



Missouri Department of Natural Resources

Biological Assessment and Metals Characterization Report

Fredericktown Area, Part 2:

**Little St. Francis River (WBID 2854),
Village Creek (WBIDs 2863 and 2864), and Saline Creek (WBID 2859)
Madison County**

Fall 2018 – Spring 2019

Prepared for:
Missouri Department of Natural Resources
Division of Environmental Quality
Water Protection Program
Water Pollution Control Branch

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Appendix A	Macroinvertebrate Bench Sheets Report, Fredericktown Area, Part 2: Little St. Francis River (fall only), Village Creek, and Saline Creek Stations, Madison County, Missouri, Fall 2018 – Spring 2019
Appendix B	Aerial Photos – Little St. Francis River, Village Creek, and Saline Creek Stations, Madison County, Missouri

1.0 Introduction

This biological assessment and metals characterization project focuses on streams in and around Fredericktown, Missouri. This report is a downstream continuation of an earlier project that included Logtown Branch, Little St. Francis River, and Shays Creek (MoDNR 2020), all of which are part of the same system as streams in this project.

Fredericktown Area Part 2 includes a biological assessment and metals characterization of Little St. Francis River (**LSFR**; WBID 2854), Village Creek (**VC**; WBIDs 2864 and 2863), and Saline Creek (**SC**; WBID 2859) in Madison County, Missouri. This study continues at a point in Little St. Francis River about 2.7 miles downstream from Logtown Branch and 2.1 miles upstream of Fredericktown City Lake. Village Creek, a receiving stream of Shays Creek, and Saline Creek are both tributaries of LSFR. All streams are located in the Ozark/Upper St. Francis/Castor River Ecological Drainage Unit (Figure 1) in Madison County, Missouri (Figure 2).

Little St. Francis River is a class P stream with a drainage area of approximately 138 square miles. It flows for approximately 32.0 miles through southeast St. Francois County into north-central Madison County (Figure 2; Table 1). The stream reaches its confluence with the St. Francis River approximately 7.5 miles west of Fredericktown (Figure 3). Little St. Francis River has beneficial use designations that include livestock and wildlife watering (**LWW**), warm water habitat (**WWH**), whole-body contact (**WBC**) – category A; cool-water fishery (**CLF**), secondary contact recreation (**SCR**), and drinking water supply (**DWS**). Whole body contact category A is defined as

...waters that have been established by the property owner as public swimming areas welcoming access by the public for swimming purposes and waters with documented existing whole body contact recreational use(s) by the public. Examples of this category include, but are not limited to: public swimming beaches and property where whole-body contact recreational activity is open to and accessible by the public through law or written permission of the landowner (MoDNR 2018c).

Village Creek (WBID 2864 for the upstream station and WBID 2863 for the downstream station) flows from east to west for approximately 7.0 miles from north-central Madison County, northeast of Mine La Motte, through Junction City to its confluence with LSFR in Fredericktown (Figures 2 and 3). Village Creek (WBID 2864) is a class C stream for approximately 1.9 miles to the Shays Creek confluence. Village Creek (WBID 2863) is a class P stream for the remaining 3.0 miles from Shays Creek to its confluence with LSFR in Fredericktown (MoDNR 2018c). The Village Creek (**VC**) watershed encompasses approximately 7.9 square miles. Its tributaries include Shays Creek and Mine La Motte (Slime Pond). Village Creek has designated beneficial uses for IRR, LWW, WWH, WBC – category B, and SCR (MoDNR 2018c). Whole body contact– category B is defined as

...waters designated for whole body contact recreation not contained in category A (MoDNR 2018c).

Saline Creek (WBID 2859) flows for approximately 6.9 miles from east to west in central Madison County through urban Fredericktown before reaching its confluence with LSFR (Figures 2 and 3). Saline Creek (SC) is a class C stream for 1.1 miles from its source to a point approximately 2.5 miles east of Fredericktown near State Highway J where it is joined by an unnamed tributary and becomes a class P stream. It then flows an additional 5.8 miles to its confluence with LSFR. The confluence is approximately 0.1 mile downstream from Village Creek. Saline Creek's watershed is approximately 17.3 square miles and includes rural Madison County, Cobalt Village, and Fredericktown. Among its tributaries are Goose Creek, an unnamed tributary near South Chamber Drive (named "Unnamed Tributary" for simplicity in this report), and Tollar Branch, all of which are in Fredericktown. The Saline Creek beneficial use designations are IRR, LWW, WWH, WBC – category B, and SCR (MoDNR 2018c).

1.1 Justification

The Fredericktown area streams included in this project are within the general vicinity of an area known as the Madison County Mines Superfund Site (United States Environmental Protection Agency [EPA] Facility ID: MOD098633415). Located in what is known as the Old Lead Belt, this area is approximately 80 miles south of St. Louis, Missouri (ATSDR 2005; EPA 2020a). The majority of the abandoned mine workings are located within 6 miles of each other and cover approximately 645 acres around the city of Fredericktown (ATSDR 2005).

Metals were discovered in the area in the early 1700s and have been a primary source of lead from the American Revolution to the Korean Conflict (MoDNR 2010). Mining continued to the mid-1900s (ATSDR 2005; EPA 2020a; MoDNR 2010). Metals mined included predominantly lead; however, copper, cobalt, nickel, iron, zinc, and silver were also mined at some locations. Past mining operations at the Madison County Mines Site have left at least 13 major tailings and chat deposits from mineral processing and smelting operations within the county (EPA 2020a). The EPA designated seven Operable Units (OU) for the site (EPA 2020a). The LSFR is subject to all OUs including Conrad Tailings (OU 4) near Mill Creek and Catherine Mines (OU 5); Village Creek drains the Northern Madison County Unit (OU 1), and Saline Creek drains Anschutz Subsite (OU 2). Operable Units are shown in Figures 2-4 and aerial photographs in Appendix B.

The EPA identified "contaminants of concern" (COC) for the Madison County Mine Site. The COCs are chemical substances that the EPA has determined pose an unacceptable risk to human health or the environment (EPA 2020b). The EPA listed arsenic, cadmium, cobalt, copper, lead, manganese, and nickel as COCs that have been found in groundwater, sediment, soil, solid waste, and surface water. The site status indicates that human exposure status is "not under control," there are "insufficient data" for contaminated groundwater status, and the site is not ready for anticipated use (EPA 2020b). The EPA and the Missouri Department of Natural Resources (MoDNR) have sampled sediment for heavy metals from the watershed and found arsenic, copper, and lead exceeding "threshold effects levels" (see MacDonald et al. 2000).

The Madison County Mine Site was added to the Superfund National Priorities List (**NPL**) on September 29, 2003, for metals contamination (including lead) in residential soil and nearby surface water bodies--the Little St. Francis River and its tributaries (EPA 2021). The primary sources of metals contamination are said to be the large, uncontained tailings and chat piles associated with local historical operations that mined for lead, copper, cobalt, nickel, iron, zinc, silver, and pyrite (EPA 2021). Tailings dispersal resulted from tailings pond breaks, runoff from piles adjacent to streams, and human removal.

In 2014, LSFR was placed on the 303(d) List of Impaired Waters for inorganic lead associated with sediment, and the protection of aquatic life (AQL, the designated use at the time) was listed as the impaired beneficial use. The listed reach extends approximately 32 miles from the Logtown Branch confluence to LSFR's confluence with St. Francis River (MoDNR 2015b; MoDNR 2016a; MoDNR 2018d). Sources for listing were suggested to be Catherine Mine and possibly Mine LaMotte. The TMDL priority is High and is expected to be developed by 2023 (MoDNR 2018d).

A TMDL was written for Village Creek (WBID 2864 and WBID 2863), Madison County (MoDNR 2010). The length of the impaired segment upstream of Shays Creek (WBID 2864) is approximately 1.5 miles, and the downstream reach (WBID 2863) is approximately 3.0 miles. The impaired beneficial use is listed as protection of warm water aquatic life by inorganic sediment (non-volatile suspended solids) and lead, with a source of Mine LaMotte abandoned mine lands and a TMDL Priority Ranking of High. The TMDL report for inorganic sediment and lead was approved by the EPA in 2010 (MoDNR 2010).

Saline Creek (WBID 2859) was placed on the 1998 303(d) list for nickel, and a TMDL was written and approved by EPA in 1999 for dissolved nickel and cobalt (MoDNR 1999). The impaired segment is 0.5 miles downstream from its confluence with Goose Creek. The source is emerging ground waters from Madison Mine with a TMDL Priority Ranking of High.

Aquatic macroinvertebrates in mine-related streams of Missouri can accumulate elevated concentrations of metals (Besser et al. 1987, 2007; Poulton et al. 2009; Allert et al. 2008, 2009, 2011). Macroinvertebrate communities appear to be negatively affected where elevated concentrations of metals are found in sediment pore water (Besser et al. 2007, 2009a, 2009b; Brumbaugh et al. 2007; Poulton et al. 2009; Allert et al. 2008, 2011). Metals in pore water generally tracked closely with metals concentrations in sediments, and metals such as cobalt, nickel, lead, and zinc were elevated near mining operations (Brumbaugh et al. 2007).

Macroinvertebrate communities continue to be affected by past mining in Fredericktown area streams. The Fredericktown area study conducted in 2015-2016 found several stations to be partially supporting of the WWH beneficial use (MoDNR 2020). A number of nutrients and turbidity were elevated compared to EPA (2000) suggested guidelines. Surface water dissolved metals concentrations were in compliance with Missouri's Water Quality Standards (**WQS**; MoDNR 2018c) at all stations. However, metals in fine sediment exceeded the probable effects concentrations (MacDonald et al. 2000) at several sites. Total lead and nickel in Logtown

Branch, total arsenic, lead, and nickel in Shays Creek #2, and total arsenic in Shays Creek #1 all exceeded fine sediment PECs. PECs are thresholds for metals in benthic sediment above which toxic effects may occur in aquatic organisms.

In this project, LSFR, VC, and SC were examined to determine their ability to support the WWH beneficial use designation. A stream habitat assessment, biological assessment (including macroinvertebrate community and physicochemical water quality analyses), surface water dissolved metals analyses, and a benthic fine sediment metals characterization were aspects included in this second study of Fredericktown area streams.

This biological assessment and metals characterization study were requested by the MoDNR Water Protection Program (**WPP**). The project was conducted by the Division of Environmental Quality (**DEQ**), Environmental Services Program (**ESP**), Water Quality Monitoring Section (**WQMS**). Laboratory water quality analyses were conducted by the MoDNR, ESP Chemical Analysis Section (**CAS**).

1.2 Objectives

- Assess the stream habitat quality.
- Assess the “protection of warm water habitat” designated beneficial use status using the benthic macroinvertebrate community.
- Assess the physicochemical water quality.
- Determine the dissolved metals concentrations in the surface water.
- Determine the heavy metals character of the fine sediment in the study streams.

1.3 Null Hypotheses

- 1) Stream habitat quality will be comparable to the stream habitat control at all stations.
- 2) Macroinvertebrate Stream Condition Index scores will indicate that LSFR, Village Creek, and Saline Creek are fully supporting of the beneficial use – for the protection of WWH, and individual biological metrics will be within the optimum scoring range of wadeable/perennial reference stream biological criteria during the fall and spring seasons.
- 3) Dominant Macroinvertebrate Taxa compositions (a secondary biological metric) will indicate that LSFR, Village Creek, and Saline Creek macroinvertebrate communities are similar to biological criteria reference streams.
- 4) Physicochemical water quality parameters will be within acceptable limits as specified in Missouri’s Water Quality Standards (MoDNR 2018c) and will not be notable relative to other guidance.
- 5) Dissolved metals in the surface water will be within acceptable hardness-dependent limits outlined in Missouri’s WQS (MoDNR 2018c) for LSFR, Village Creek, and Saline Creek.
- 6) Total metals levels associated with benthic fine sediment (arsenic, cadmium, cobalt, copper, lead, nickel, silver, and zinc) will be below potentially toxic threshold levels in LSFR, Village Creek, and Saline Creek.

2.0 Methods

Kenneth B. Lister, Carl Wakefield, Olivia Jackson, Dave Gullic, and other ESP personnel were involved in this study. The study timing is outlined in this section. The study area and station descriptions, Ecological Drainage Units, and land uses are provided. Stream habitat assessment procedures are discussed. Biological assessment procedures that include macroinvertebrate and physicochemical water collection methods and analyses are discussed in this section. Surface water and benthic fine sediment collection methods are provided.

2.1 Study Timing

Sampling was conducted in fall 2018 and spring 2019 (Table 1). Sediment samples were collected in mid-July 2018. Stream habitat assessments were conducted in July, September, or October. Macroinvertebrate and water samples were collected in mid-September to early October 2018 at all stations. Spring macroinvertebrate and water samples were collected in mid-March 2019 at Village Creek and Saline Creek stations; however, LSFR stations were not sampled in spring 2019 due to high flow and non-wadeable conditions.

2.2 Study Area, Station Locations, and Descriptions

A total of seventeen monitoring stations were used for this project (Table 2; Figure 2). Eleven stations were sampled in LSFR (including one that was sampled only for sediment), two in Village Creek, and four in Saline Creek (Figures 2 and 3). One additional station on Castor River (2297/37.0) was used as a stream habitat control. Stations were positioned to bracket potential influences, identify influences, and to determine the downstream extent of influences. Ten biological assessment and fine sediment sample stations were placed in a 21 mile reach of LSFR from upstream near CR 220 (Copper Mines Road) to near the confluence with the St. Francis River (Figures 2, 3, and 4). Station locations were intended to bracket points of interest and identify the presence and extent of influence. The length of each station was approximately 20 times the average width of the stream, as stated in the *Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP; MoDNR 2019a)*. Rabeni et al. (1999) found this station length to be adequate for sampling macroinvertebrate communities, and a single reach can be representative of an entire stream segment (MoDNR 2019a).

2.2.1 Ecological Drainage Unit

The Fredericktown area streams are located in the Ozark/Upper St. Francis/Castor Ecological Drainage Unit (EDU; Figure 1). An EDU is an area that is delineated and identified by its natural terrestrial physiographic division and major riverine watershed components. EDUs are described in detail by Sowa et al. (2007). Streams of similar size within an EDU are expected to provide similar habitat conditions and biological communities. As such, stream habitat, biological, and physicochemical components should be comparable between test streams and reference streams within the same EDU.

Table 1
 Sample Timing – Field Sampling Schedule on Month-Day in Fall 2018/Spring 2019

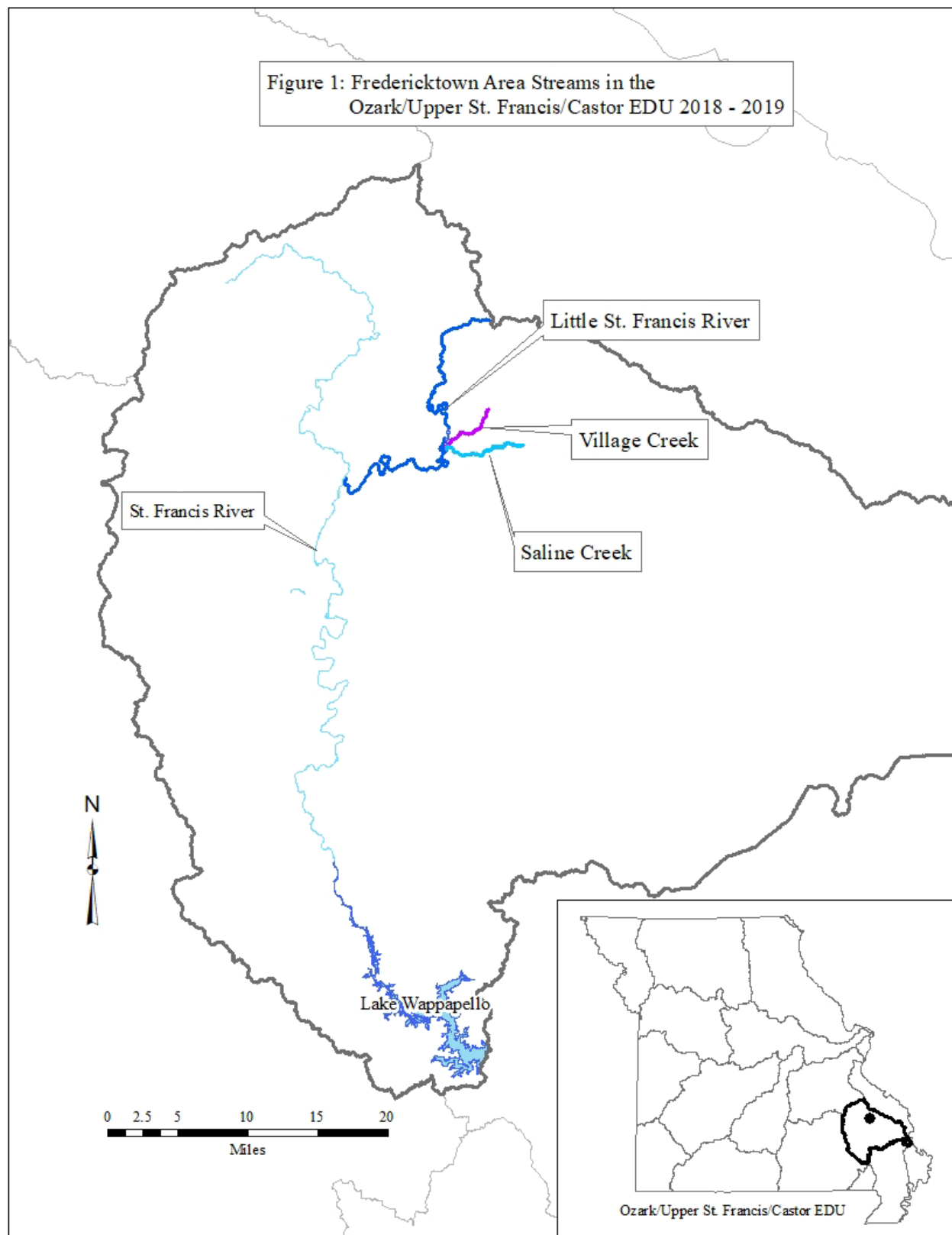
Stream and Station Number	Sediment	SHAPP	Macroinvertebrate	Water
LSFR 21.2	7-10	9-24	9-24	10-2
LSFR 21.1	7-10	9-24	9-24	10-2
LSFR 16.6	7-11	10-1	10-1	10-1
LSFR 16.3	7-11	10-1	10-1	10-1
LSFR 16.0	7-11	10-1	10-1	10-1
LSFR 13.7	7-18	7-18	10-2	10-2
LSFR 13.2	7-10*	--	--	--
LSFR 13.0	7-10	7-18	10-2	10-2
LSFR 10.4	7-11	7-18	9-24	10-2
LSFR 3.0	7-23	7-23	10-2	10-2
LSFR 0.4	7-23	7-23	10-2	10-2
Village Cr. 2864/0.2	7-18	7-18	9-26 / 3-18	9-26 / 3-18
Village Cr. 2863/1.7	7-18	7-18	9-26 / 3-18	9-26 / 3-18
Saline Cr. 3.2	7-17	7-17	9-25 / 3-19	9-25 / 3-19
Saline Cr. 2.0	7-17	7-17	9-25 / 3-19	9-25 / 3-19
Saline Cr. 1.3	7-17	7-17	9-25 / 3-19	9-25 / 3-19
Saline Cr. 1.2	7-17	7-17	9-25 / 3-19	9-25 / 3-19
Castor River 38.0	7-10	7-17	--	--

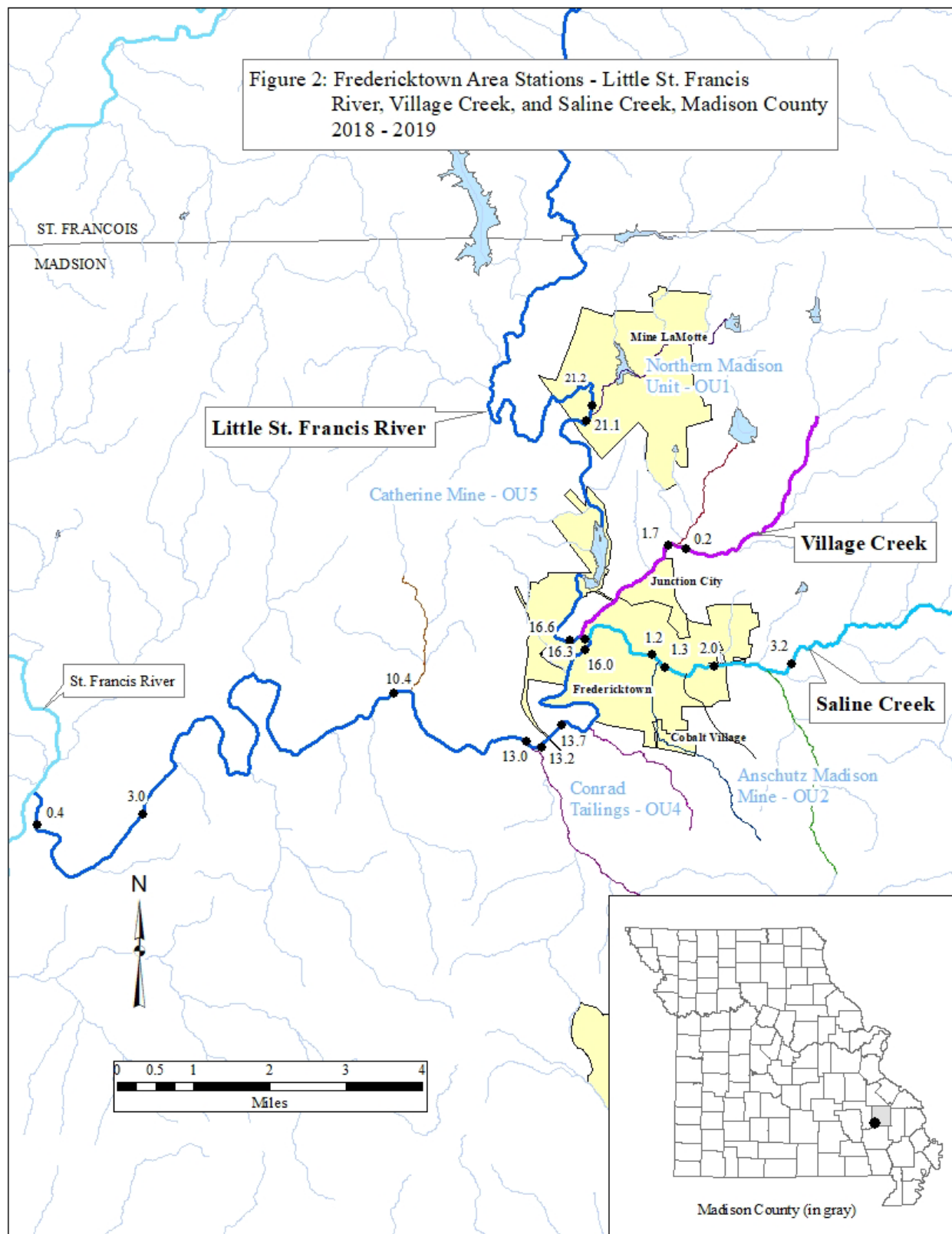
LSFR = Little St. Francis River; SHAPP = Stream Habitat Assessment Project Procedure; * = only sediment samples were collected at this site; -- = not sampled

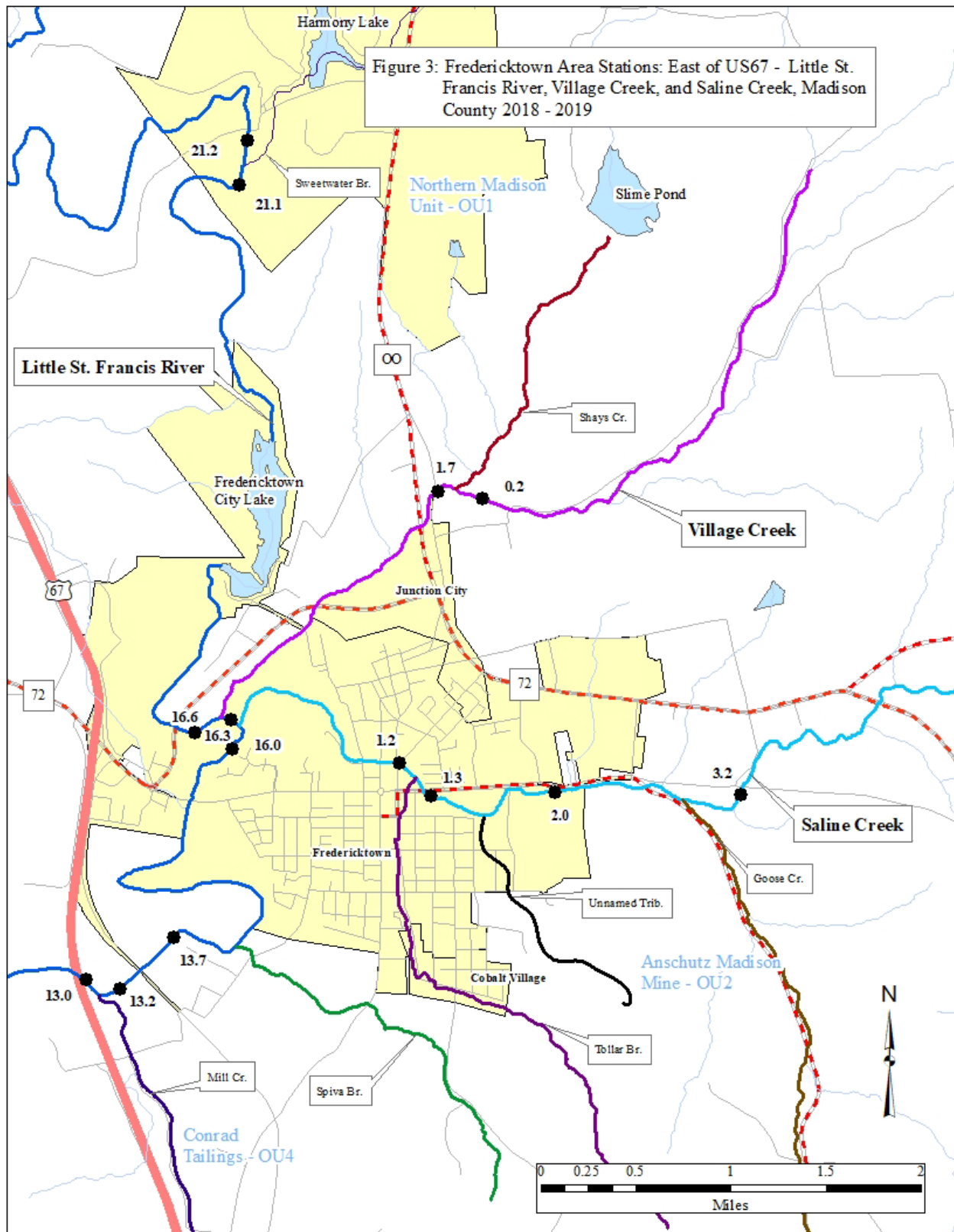
Table 2
 Locations and Descriptions of Stations in the Fredericktown Area Study, Madison County,
 Missouri 2018-2019

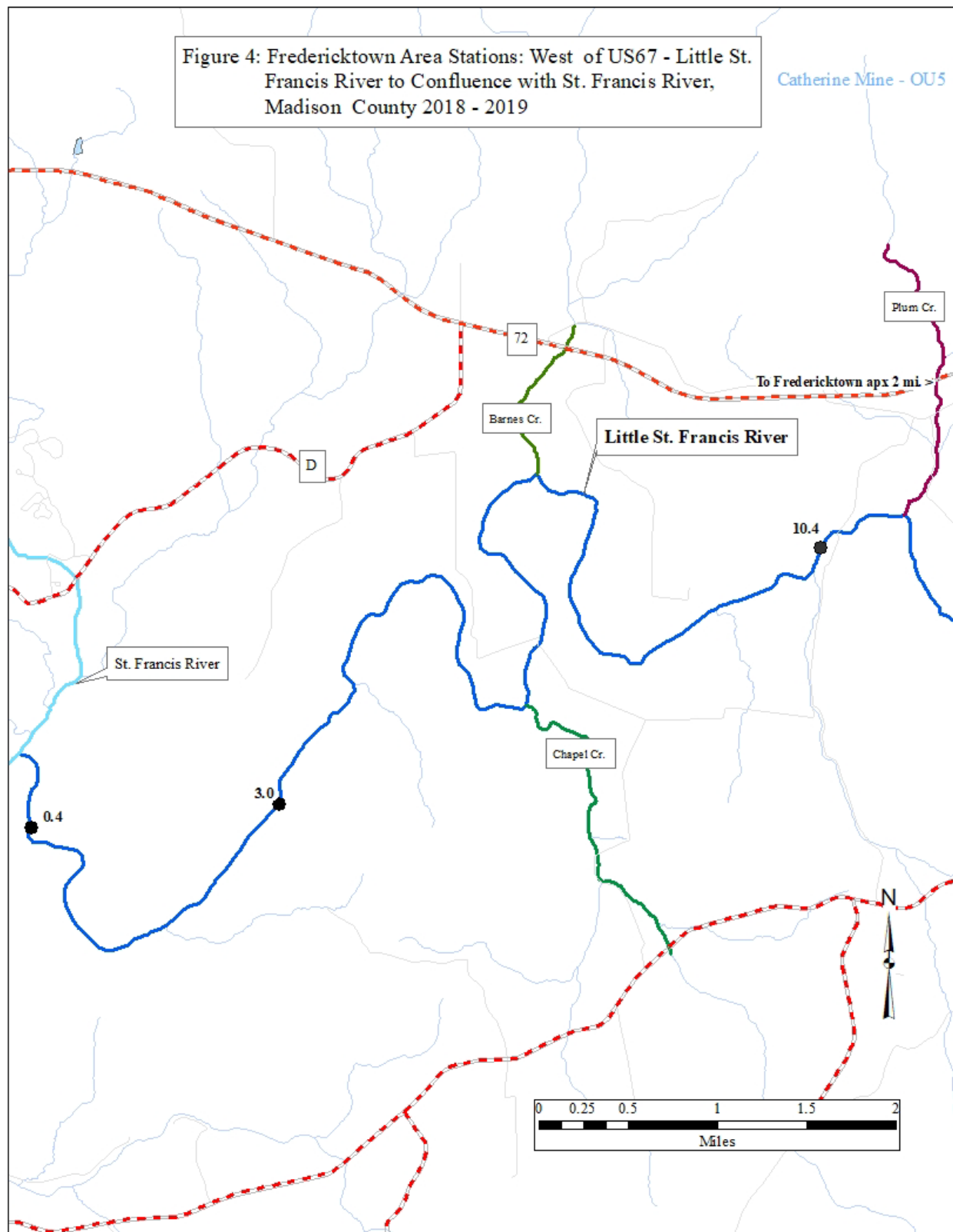
Stream and Station Number	Location	Description	WBID	Purpose	Class
LSFR 21.2	NW ¼ sec. 31, T. 34 N., R. 07 E. UTME 737845, UTMN 4165821	US Sweetwater Br.; 2854	2854	Test	P
LSFR 21.1	NW ¼ sec. 31, T. 34 N., R. 07 E. UTME 737828, UTMN 4165693	DS Sweetwater Br.	2854	Test	P
LSFR 16.6	SW ¼ sec. 07, T. 33 N., R. 07 E. UTME 737471, UTMN 4160945	US Village Cr.	2854	Test	P
LSFR 16.3	S ½ sec. 07, T. 33 N., R. 07 E. UTME 737689, UTMN 4161009	DS Village Cr./US Saline Cr.	2854	Test	P
LSFR 16.0	NW Land Grant 03315 UTME 737794, UTMN 4160823	DS Saline Cr.	2854	Test	P
LSFR 13.7	SW Land Grant 02075 UTME 737271, UTMN 4159215	DS Spiva Br./US Mill Cr.	2854	Test	P
LSFR 13.2	NW Land Grant 02054 UTME 736707, UTMN 4158698	At Mill Cr.	2854	Sed. Test only	P
LSFR 13.0	NE Land Grant 00836 UTME 736491, UTMN 4158779	DS Mill Cr.	2854	Test	P
LSFR 10.4	NW Land Grant 01872 UTME 733434, UTMN 4159782	DS Thompson Ford CA, MDC	2854	Test	P
LSFR 3.0	NW ¼ sec. 20, T. 33 N., R. 06 E. UTME 728468, UTMN 4157591	DS Baptist Camp	2854	Test	P
LSFR 0.4	NE ¼ sec. 24, T. 33 N., R. 05 E. UTME 726137, UTMN 4157148	US confluence w/SFR	2854	Test	P
Village Creek 0.2	NE Land Grant 03323 UTME739693, UTMN4162924	US Shays Cr.	2864	Test	C
Village Creek 1.7	NE Land Grant 03323 UTME739603, UTMN4162965	DS Shays Cr.	2863	Test	P
Saline Creek 3.2	SE Land Grant 03323 UTME 741975, UTMN 4160269	US Goose Cr.	2859	Test	P
Saline Creek 2.0	NW ¼ sec., 09, T33 N., R. 07 E. UTME 740177, UTMN 4160401	DS Goose Cr. impaired/ US Unnamed Trib	2859	Test	P
Saline Creek 1.3	NW Landgrant02075 UTME 739313, UTMN 4160462	DS Unnamed Trib/ US Tollar Br.	2859	Test	P
Saline Creek 1.2	NW Land Grant 02075 UTME739256, UTMN4160548	DS Tollar Br.	2859	Test	P
Castor River 38.0	SW ¼ sec. 10, T. 33 N., R. 08 E. UTME 729819, UTMN 4127313	US CR208, Amidon CA, MDC	2297	SHAPP/ Sed. Control	P

LSFR = Little St. Francis River; SFR = St. Francis River; WBID=Water Body ID; P=Permanent flow;
 C=Conditional flow; SHAPP Stream Habitat Project Procedure (MoDNR 2016b); Sed. = Fine Sediment;
 CR=County Road; CA=Conservation Area; MDC=Missouri Department of Conservation; US = upstream; DS =
 downstream









2.2.2 Land Use Description

Land use categories of Fredericktown area stream watersheds are presented in Tables 3 and 4. The percentage of each land use for each station was based on their respective 12-digit Hydrological Unit Code (**HUC-12**). The percent land use data were derived from Thematic Mapper satellite data collected between 2000 and 2004 and interpreted by the Missouri Resource Assessment Partnership (**MoRAP**). The percentage of each land use category at each station was compared to the overall Ozark/Upper St. Francis/Castor EDU.

LSFR Land Uses

Land uses at LSFR stations were generally similar to those in the Ozark/Upper St. Francis/Castor EDU (Table 3). Forest was the dominant land use at all LSFR stations and the EDU, although it was more abundant in the EDU. Grassland was the second most prevalent land use at all stations and the EDU, although it was more abundant for LSFR study sites than in the EDU. These two categories accounted for over 80 percent of all land uses. Cropland was more prevalent in the EDU than the (mostly) urban LSFR stations, although it made up only a small percentage of the total. The percentage of urban, barren, and impervious surface land covers was higher in five LSFR stations that were located in Mine LaMotte and Fredericktown. Although there appeared to be only slight differences in land use among these LSFR stations, the differences are worth noting. Urban, impervious, and barren land uses combined to make up 8.7 percent of the watershed from LSFR 21.1 downstream to LSFR 13.2, which included stations located within the city limits of Mine LaMotte and Fredericktown. Although urban land use was relatively minor (3.9 percent), when combined with impervious and barren (which likely include areas affected by mining) the cumulative effects of these three land uses on the aquatic community may be ecologically important. By comparison, the remaining LSFR stations upstream and downstream had no more than 2.2 percent of urban, impervious, and barren land use combined.

Village Creek and Saline Creek Land Uses

Village Creek and Saline Creek land uses were compared to those in the Ozark/Upper St. Francis/Castor EDU (Table 4). Forest was the dominant land cover at all test stations and the EDU. Grassland was the second most abundant land cover at the stations, as well as the EDU. Together, forest and grassland accounted for over 80 percent of the total land use. Village and Saline creeks had slightly more impervious surface and urban land cover, as the stations were located within either Junction City or Fredericktown. Urban land use made up less than 4 percent compared to 1 percent for the EDU. Barren and impervious surfaces may be remnants of past land use practices and may be actual contributors to results found in this study.

2.3 Stream Habitat Assessment Project Procedure

The *Stream Habitat Assessment Project Procedure* (**SHAPP**) was followed as described for riffle/pool prevalent streams (MoDNR 2016b). According to the SHAPP, stream habitat can affect the quality of the biological community. Stream habitat quality of test streams is compared to the habitat quality of a control stream (SHAPP control). Stream habitat features are given numeric scores based on visual assessments of test stations and the SHAPP control. Each feature has a possible 20 points for a potential 200 point total score. Each test station score is expressed

as a percentage of the SHAPP control. If a test station SHAPP score is ≥ 75 percent of the control score, the stream habitat at that test station is considered to be comparable to the control. Castor River 38.0 (WBID 2297) in Madison County, served as the SHAPP control for this study (Tables 4 and 5).

Table 3
 Percent Land Use/Cover for Little St. Francis River (LSFR) Stations (HUC-12) and the
 Ozark/Upper St. Francis/Castor EDU

Land-Use HUC-12 080202020-	Impervious	Urban	Barren	Crop	Grass	Forest	Woody /Herb	Wetland	Water
LSFR 21.2 -101	0.7	1.0	0.5	2.4	34.3	45.7	12.7	1.0	1.6
LSFR 21.1 -102	2.5	3.9	2.3	1.1	33.0	47.5	7.9	0.4	1.4
LSFR 16.6 -102	2.5	3.9	2.3	1.1	33.0	47.5	7.9	0.4	1.4
LSFR 16.3 -102	2.5	3.9	2.3	1.1	33.0	47.5	7.9	0.4	1.4
LSFR 16.0 -102	2.5	3.9	2.3	1.1	33.0	47.5	7.9	0.4	1.4
LSFR 13.7 -102	2.5	3.9	2.3	1.1	33.0	47.5	7.9	0.4	1.4
LSFR 13.2 -102	2.5	3.9	2.3	1.1	33.0	47.5	7.9	0.4	1.4
LSFR 13.0 -103	0.4	0.4	0.4	0.8	34.0	53.4	8.9	0.5	1.3
LSFR 10.7 -103	0.4	0.4	0.4	0.8	34.0	53.4	8.9	0.5	1.3
LSFR 3.0 -103	0.4	0.4	0.4	0.8	34.0	53.4	8.9	0.5	1.3
LSFR 0.4 -103	0.4	0.4	0.4	0.8	34.0	53.4	8.9	0.5	1.3
EDU	0.7	1.0	0.3	8.1	23.2	59.7	3.7	1.5	1.9

Table 4
 Percent Land Use/Cover for Village Creek (VC) and Saline Creek (SC) Stations (HUC-12), and
 the Ozark/Upper St. Francis/Castor EDU

Land-Use HUC-12 080202020-	Impervious	Urban	Barren	Crop	Grass	Forest	Woody /Herb	Wetland	Water
VC 0.2 -102	2.5	3.9	2.3	1.1	33.0	47.5	7.9	0.4	1.4
VC 1.7 -102	2.5	3.9	2.3	1.1	33.0	47.5	7.9	0.4	1.4
SC 3.2 -102	2.5	3.9	2.3	1.1	33.0	47.5	7.9	0.4	1.4
SC 2.0 -102	2.5	3.9	2.3	1.1	33.0	47.5	7.9	0.4	1.4
SC 1.3 -102	2.5	3.9	2.3	1.1	33.0	47.5	7.9	0.4	1.4
SC 1.2 -102	2.5	3.9	2.3	1.1	33.0	47.5	7.9	0.4	1.4
EDU	0.7	1.0	0.3	8.1	23.2	59.7	3.7	1.5	1.9

2.4 Biological Assessment

This biological assessment was conducted using methods described in the SMSBPP (MoDNR 2019a). A biological assessment involves examination of the macroinvertebrate community using biological metrics and physicochemical water quality variables. Primary metrics are numeric descriptions of the macroinvertebrate community structure that are ultimately used to assess a stream's ability to support its beneficial use designation. Secondary metrics are used to further examine macroinvertebrate communities that may also identify possible sources of influence. Water quality constituents are examined for trends, notable results, and compared to Missouri's Water Quality Standards (MoDNR 2018c), as well as other available thresholds. Biological assessments are grouped by year and station.

2.4.1 Macroinvertebrate Sampling, Identification, and Analyses: Primary Metrics

Macroinvertebrate samples were collected from multiple habitats as described in the SMSBPP (MoDNR 2019a). Fredericktown area stations are considered to be riffle/pool dominant streams. As such, coarse substrate (**CS**; riffle), non-flowing water over depositional substrate (**NF**), and rootmat (**RM**) habitats were sampled. In the WQMS laboratory, macroinvertebrates were acquired from subsamples of the benthic material collected for each habitat as described in the SMSBPP (MoDNR 2019a). These macroinvertebrates were then identified to specific taxonomic levels (MoDNR 2019b). Primary metrics generated from these macroinvertebrate data are used to calculate the Macroinvertebrate Stream Condition Index (**MSCI**).

A stream condition index using macroinvertebrates was developed as a measurement of a stream's biological integrity (Rabeni et al. 1997). The index was further refined to include biological criteria that were generated using wadeable/perennial biological reference streams

(**BIOREF**) for each EDU, as described in *Biological Criteria for Perennial/Wadeable Streams* (MoDNR 2002). Now called the Macroinvertebrate Stream Condition Index (MSCI), this semi-quantitative rank score is derived by comparing test station metric values to BIOREF criteria.

An MSCI score is developed by a multi-metric assessment of the macroinvertebrate community composition. The four primary biological metrics used to calculate the MSCI are Taxa Richness (**TR**), Ephemeroptera/Plecoptera/Trichoptera Taxa (**EPTT**), Biotic Index (**BI**), and Shannon Diversity Index (**SDI**). Each metric value is compared to the BIOREF criteria values. Metrics then receive individual scores of 5, 3, or 1 based where the values fall relative to BIOREF criteria. The four individual metric scores are added to calculate the MSCI score. The MSCI score is then related to the following biological support categories: 20-16 = fully supporting; 14-10 = partially supporting; and 8-4 = non-supporting of the WWH beneficial use designation. MSCI scores were examined by station and grouped by season.

2.4.2 Macroinvertebrate Analyses: Secondary Metrics

Secondary metrics are used to highlight or further analyze findings of the primary metrics and may assist in identifying sources of impairment. One secondary metrics was used for this project. The Dominant Macroinvertebrate Taxa (**DMT**) was used according to the SMSBPP (MoDNR 2019a) to identify similarities between macroinvertebrate communities of BIOREF streams (in aggregate) and test stations.

The DMT metric is a comparison between BIOREF communities and test stations based on abundance of each taxon. The DMT metric lists the top 10 most abundant taxa in BIOREF streams of the EDU. All DMT are then compared to their presence and abundance among test stations. A DMT that is absent or ranked outside the top 10 (i.e. substantially reduced, ranked lower) may suggest a stressor is limiting its presence. Presence of a majority of DMT in similar abundance at a station suggests there are few or no stressors; a minority of DMT in a station suggests there may be stressors shaping the community composition.

A complete taxa list is provided in Appendix A. The *Macroinvertebrate Database Bench Sheet Report* may be used to further examine specific taxa occurrence. The bench sheet report is grouped by season and station.

2.4.3 Physicochemical Water Sampling and Analyses

Physicochemical water samples were collected and analyzed according to applicable Standard Operating Procedures (**SOPs**). Results for physicochemical water variables were examined by year and station.

Physicochemical water constituents were measured in the field or analyzed at the ESP State Environmental Laboratory in Jefferson City, Missouri. Water was sampled according to SOP MDNR-ESP-001 *Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations* (MoDNR 2018f). Temperature (°C), pH, specific conductance (µS/cm), dissolved oxygen (mg/L), and discharge (cubic feet per second-**cfs**) were measured *in situ*. The ESP's CAS conducted analyses for ammonia as nitrogen (**NH₃-N**; mg/L), nitrate+nitrite as nitrogen (**NO₃+NO₂-N**; mg/L), total nitrogen (**TN**; mg/L), chloride (**Cl**; mg/L),

sulfate (**SO₄**; mg/L), total phosphorus (**TP**; mg/L), and non-filterable residue (**NFR**; mg/L). Turbidity (nephelometric turbidity units, **NTU**) was measured and recorded in the WQMS biology laboratory. All samples to be analyzed at ESP were kept on ice during transport.

Surface water physicochemical results were compared to Missouri's Water Quality Standards (**WQS**; MoDNR 2018c) and suggested guidelines. Because Missouri does not currently have nutrient criteria for streams and rivers, nutrient values were compared to suggested guidelines contained in *Ambient Water Quality Criteria Recommendations for Rivers and Streams in Nutrient Ecoregion XI* (EPA 2000). The EPA *Aggregate Nutrient Ecoregion XI, level III (sub) ecoregion 39* recommended reference condition values used for comparison were as follows: NO₃+NO₂-N (0.239 mg/L), turbidity (1.425 NTU), TN (0.379 mg/L), and TP (0.006625 mg/L).

Although the suggested guidelines listed above contain scientific recommendations regarding ambient concentrations of nutrients that protect aquatic resource quality, they do not substitute for Clean Water Act (**CWA**) or EPA regulations, nor are they regulations themselves. The criteria were empirically derived to represent conditions of surface waters that are minimally affected by human activities and are protective of aquatic life and recreational uses (EPA 2000).

2.4.4 Discharge

Stream discharge was measured using a Marsh-McBirney Model 2000 Flo-Mate™ flow meter and wading rod at each station. Velocity and depth measurements were recorded, and discharge was calculated according to SOP MDNR-ESP-113 *Flow Measurement in Open Channels* (MoDNR 2015a).

2.5 Surface Water: Dissolved Metals

Surface water samples were analyzed for dissolved metals by ESP's CAS. Water grab samples were filtered using a 0.45 µm filter, preserved, and handled as outlined in MDNR-ESP-001 (MoDNR 2018f). Dissolved metals included in this project were arsenic (**As**), barium (**Ba**), cadmium (**Cd**), calcium (**Ca**), cobalt (**Co**), copper (**Cu**), Iron (**Fe**), lead (**Pb**), magnesium (**Mg**), manganese (**Mn**), nickel (**Ni**), silver (**Ag**), and zinc (**Zn**). Hardness as CaCO₃ values were calculated using Ca and Mg according to the American Public Health Association (APHA 2012) Standard Methods (2340 B, 2011). Results were compared to hardness dependent chronic and acute toxicity thresholds for heavy metals described in Missouri's Water Quality Standards (MoDNR 2018c). These limits are based on the lethality of a toxicant given long-term (chronic toxicity) or short-term (acute toxicity) exposure.

2.6 Fine Sediment: Total Metals Characterization

Instream deposits of benthic fine sediment (i.e. particle size <2.0 mm) were collected, and total recoverable metals content was analyzed by ESP's CAS. Fine sediments were analyzed for total recoverable As, Cd, Co, Cu, Pb, Ni, Ag, and Zn. Notable results are those that exceed or are near threshold concentrations determined by MacDonald et al. (2000) or MacDonald and MacFarlane (1999) for individual metals (PEC, PEQ described below), or concentrations published in MacDonald et al. (2009) for effects from a mixture or combination of these metals (Σ PEQ_{Cd, Pb, Zn} and mean PEQ_{metals}). These are levels above which toxic effects may potentially be observed

on the aquatic community. Castor River (Station 38.0) fine sediment was used for relative comparison with test stations.

Fine sediment was collected from all stations in the fall of 2018. An 8-ounce glass jar was used to dredge fine sediment from the substrate no deeper than 2 inches. Sediment from several jars was composited, sieved to size (<2.0 mm), and subsampled into a glass sample jar according to MDNR-ESP-011 *General Sampling Considerations for Chemical Analysis of Sediments* (MoDNR 2018a). Samples were delivered to ESP's CAS for metals analyses. Individual total metals concentrations and mixture or combination of metals quotients were compared to threshold levels (mg/kg).

Individual metals concentrations were compared to Probable Effects Concentrations (PECs; MacDonald et al. 2000). A PEC is a threshold level for a contaminant, above which harmful effects are likely to be observed. MacDonald et al. (2000) found PECs to be reliable for 10 metals (including cadmium, lead, and zinc) in classifying sediments as potentially toxic or nontoxic to sediment-dwelling organisms. The PEC for arsenic = 33.9 mg/kg, cadmium = 4.98 mg/kg, copper = 149 mg/kg, lead = 128 mg/kg, nickel = 48.6 mg/kg, silver = 2.2 mg/kg*, and zinc = 459 mg/kg (MacDonald et al. 2000; *MacDonald and MacFarlane 1999).

Individual metals were also examined using a Probable Effects Concentration Quotient (PEQ; MacDonald et al. 2000, 2009; Ingersoll et al. 2001, 2002, 2009; Besser et al. 2008, 2009a). A PEQ is the total recoverable metal concentration divided by the PEC threshold for that metal (MacDonald et al. 2000). A PEQ greater than 1.0 may indicate an increased risk of toxicity due to the concentration of that metal (Ingersoll et al. 2001; Besser et al. 2009a).

Individual metals concentrations were compared to the Tri-State Mining District (TSMD; MacDonald et al. 2009) site specific thresholds (T_{10}) and reported if notable to further assess the potential risk of toxicity to benthic invertebrates. A level above a T_{10} value corresponds to a 10 percent reduction in the control-adjusted survival or biomass of amphipods, midges, or mussels compared to the average response rate for toxicity test organisms exposed to reference sediments. The TSMD threshold (T_{10}) for cadmium = 11.1 mg/kg, lead T_{10} = 150 mg/kg, and zinc T_{10} = 2083 mg/kg.

The toxic effects from a mixture or combination of metals were examined using the sum of PEQs for cadmium, lead, and zinc ($\sum \text{PEQ}_{\text{Cd, Pb, Zn}}$) or the mean PEQ for all metals (**mean PEQ_{metals}**). The $\sum \text{PEQ}_{\text{Cd, Pb, Zn}}$ is the sum of PEQs that identifies potential toxicity due to the mixture or combination of these metals (Ingersoll et al. 2001; Besser et al. 2009a, 2009b; MacDonald et al. 2000, 2009; Allert et al. 2011). The mean $\text{PEQ}_{\text{metals}}$ is suggested to normalize the sample result (Long et al. 1998; MacDonald et al. 2000, 2009; Ingersoll et al. 1998, 2001, 2002, 2009; Besser et al. 2008, 2009b). The mean $\text{PEQ}_{\text{metals}}$ is the $\sum \text{PEQs}$ for all metals, excluding cobalt (for which no PEQ currently exists), divided by the number of metals included in the mixture ($n = 7$). Although the $\sum \text{PEQ}$ and the mean PEQ are included for comparison, both are individually effective in predicting potential toxicity due to a mixture or combination of metals. The T_{10} used for $\sum \text{PEQ}_{\text{Cd, Pb, Zn}} = 7.92$ and the mean $\text{PEQ}_{\text{metals}} = 1.11$ (MacDonald et al. 2009). Quotients

above these thresholds suggest the mixture or combination of metals associated with the fine sediment may be potentially toxic to the benthic-dwelling macroinvertebrate community.

2.7 Quality Control

Quality assurance for this study is outlined in the FY 2019 Quality Assurance Project Plan (QAPP; MoDNR 2018e), the ESP SOP MDNR-ESP-210 *Quality Assurance/Quality Control for Environmental Data Collection* (MoDNR 2018b), and the SMSBPP (MoDNR 2019a). Several duplicate samples among the field team's assigned streams were collected at Fredericktown area streams. A duplicate macroinvertebrate sample was collected, analyzed, and compared using the Quantitative Similarity Index (QSI). This index is a gauge of sampling consistency between collectors, as well as accuracy in taxa identification. Duplicate surface water and fine sediment samples were collected and analyzed for at least every 10 samples to assess consistency and accuracy in collection and analyses (MoDNR 2018a). The acceptable Relative Percent Difference (RPD) between samples should be ≤ 20 percent according to the QAPP. Additionally, Castor River 38.0 served as a control site for SHAPP analysis and fine sediment metals for relative comparisons.

Duplicate macroinvertebrate, water chemistry, dissolved metals, and fine sediment samples were collected in Fredericktown area streams during this project. Duplicate macroinvertebrate samples were collected at Village Creek 1.7 on March 18, 2019 (Table 8). Duplicate water chemistry and dissolved metals samples were collected at Village Creek 0.2 on September 26, 2018 (Table 14; Table 17), and Village Creek 1.7 on March 18, 2019 (Table 15; Table 18). Duplicate fine sediment samples were collected for metals characterization at LSFR 21.2 and LSFR 16.3 on July 10, 2018 (Table 19). Results and comparisons are examined and discussed in Section 3.3.

3.0 Results/Discussion

Due to the large area of study and number of stations included for three Fredericktown area study streams, the results and discussion sections were combined for ease of use. The first section (Section 3.1) includes examination of all aspects in the biological assessment and fine sediment metals characterization for each stream and station. A summary combines all aspects to discuss the status and identify influences at each station. Additionally, overall areas of interest are identified for each stream. Section 3.2 provides an overview of general conditions in each stream, and determines whether the tributaries (in this case VC and SC) influenced conditions in LSFR. Lastly, quality assurance and quality control are discussed in Section 3.3.

3.1 Streams and Stations

This section describes the status and condition (i.e. physical, biological, and chemical) of each stream by examining all aspects included in this project. Aspects include the stream habitat assessment (SHAPP), primary biological metrics (MSCI), the Dominant Macroinvertebrate Taxa (DMT) secondary metric, physicochemical water quality analyses, dissolved metals, and fine sediment metals characterization. The section is arranged by stream – Little St. Francis River (LSFR), Village Creek (VC), and Saline Creek (SC) – and by station from upstream to downstream.

3.1.1 Little St. Francis River (LSFR) Stations

Aspects of the biological assessment and fine sediment characterization project were examined to identify the status or ability of each station to support the beneficial use, as well as the physical and chemical conditions at and among stations. A summary of results at each station may identify potential influences at that station. An overall look at potential influences may identify specific areas of interest in each stream. LSFR stations are arranged from upstream to downstream.

Station LSFR 21.2 – LSFR Upstream of Sweetwater Branch

Stream Habitat Assessment

The stream habitat assessment score at LSFR 21.2 was 83 percent of the SHAPP control and was considered comparable (Table 5). Lower epifaunal substrate, heavy sediment deposition, and very little vegetative protection on both banks reduced the score. Banks were very stable, so the sediment load was not from local bank sloughing. Although stream habitat was considered to be comparable to the SHAPP control, heavy sediment deposition may influence the macroinvertebrate community composition.

Macroinvertebrate Stream Condition Index

LSFR 21.2 had a partially supporting MSCI score of 12 in fall 2018 (Table 7). All individual metric values had suboptimal scores. The community composition differed from the BIOREF condition by having fewer taxa, less sensitive taxa, more tolerant taxa, and a less diverse community. This is the most upstream station in LSFR for this study, so any source(s) affecting the community composition was (were) upstream of or within the station.

Dominant Macroinvertebrate Taxa

The LSFR 21.2 DMT composition was compared to BIOREF streams in the fall (Table 10). Five DMT were in common with the BIOREF streams. *Caenis anceps* was prevalent at this and few other stations, and the remaining DMT were commonly found in LSFR stations. Five of the remaining DMT were absent (1 taxon) or ranked low (4 taxa) at LSFR 21.2. *Maccaffertium mediopunctatum*, the most commonly missing DMT from LSFR stations, was the only DMT absent from the sample. Similarly, the remaining DMT that ranked low at LSFR 21.2 were commonly absent or ranked low at most other LSFR stations. Based on DMT analysis, the macroinvertebrate community was not similar to those found in BIOREF streams.

Water Quality

Several water quality constituents were notable or exceeded EPA (2000) suggested guidelines at LSFR 21.2 in fall (Table 13), but none exceeded WQS (MoDNR 2018c). Discharge (6.2 cfs) was one of the lower values among LSFR stations. Specific conductance (229 μ S/cm), sulfate (11.0 mg/L), and chloride (6.53 mg/L) were also among the lower values in LSFR. Turbidity (4.2 NTU), total nitrogen (0.52 mg/L), nitrate+nitrite as N (0.24 mg/L), and total phosphorus (0.056 mg/L) exceeded EPA (EPA 2000) guidelines; all but turbidity were also among the lower concentrations in LSFR. Turbidity was second highest among stations. Ammonia-N (0.034 mg/L) was also detected.

Dissolved Metals

Dissolved metals were present in the fall surface water sample at LSFR 21.2 (Table 16). Iron (223 µg/L) was present in a much higher concentration than most other Fredericktown area stations, and lead (2.15 µg/L) was near the MoDNR WQS (MoDNR 2018c) chronic toxicity threshold (2.82 µg/L at a hardness of 111 mg/L as CaCO₃). Manganese (69.4 µg/L) was present, but nickel (<0.05 µg/L) was not detected at this station.

Fine Sediment Metals

One fine sediment metal was notable in the duplicate sample at LSFR 21.2 (Table 19; Figure 9). Lead exceeded the PEC threshold (128.0 mg/kg) in the LSFR 21.2A sample (129.0 mg/kg), but not in the LSFR 21.2B duplicate (90.8 mg/kg). The different results from the same sample may be related to the uneven distribution of metals in the composited fine sediment sample, and subsampling for analyses by CAS (See Section 3.3). Regardless, the samples identified a range of metal levels that includes one that exceeded the PEC threshold, and was nearly 3-times higher than the Castor River control. All other metals were well below PEC thresholds. The $\sum \text{PEQ}_{\text{Cd, Pb, Zn}}$ for both LSFR 21.2A (1.03) and LSFR 21.2B (0.76) were below the threshold (≥ 7.92), and the mean $\text{PEQ}_{\text{metals}}$ values for all metals combined (0.21 and 0.19, respectively) were also below the threshold (mean $\text{PEQ}_{\text{metals}} \geq 1.11$). Lead in the duplicate samples did not exceed the TSMD site-specific criterion ($T_{10} = 150 \text{ mg/kg}$).

Summary

LSFR 21.2 attained a partially supporting MSCI score with a DMT assemblage that was not substantially different from BIOREF stream communities of the EDU. Although overall stream habitat was comparable to the SHAPP control, fine sediment covered a substantial portion of the substrate, which may have influenced the community composition. Water quality analyses did not identify potential causes of aquatic community effects at this station. The dissolved lead concentration was near, but did not exceed the WQS chronic toxicity threshold, which indicated there was an upstream or instream source that could influence the aquatic community. The total fine sediment lead concentration exceeded the PEC toxicity threshold. Fine sediment metals were potential influences on the community composition and the station's ability to support the beneficial use. LSFR 21.2 is the most upstream station in this study. Local banks were stable, so potential contributors of the metals-rich fine sediment may be upstream. In an earlier study upstream (MoDNR 2020), heavy metals including lead were observed in fine sediment at Logtown Branch, a tributary to LSFR, and the LSFR station immediately downstream. Logtown Branch drains the Catherine Mine watershed to the east and is located approximately 2.0 miles upstream of LSFR 21.2 (OU 5; see MoDNR 2020). Logtown Branch or other sources located between the two studies may have contributed the dissolved metals and fine sediment metals to LSFR 21.2.

Station LSFR 21.1 – Downstream of Sweetwater Branch

Stream Habitat Assessment

Stream habitat at LSFR 21.1 was considered comparable with an 80 percent similarity to the SHAPP control stream (Table 5). Features such as less epifaunal substrate, heavy sediment deposition, poor riffle quality, low bank stability of the left bank, and little vegetative protection

reduced the score. The left bank was not stable and may have contributed to the instream sediment load. This station is one of three (LSFR 21.1, LSFR 16.6, and LSFR 13.7) to have heavy sediment deposition and poor riffle quality. Although stream habitat was considered to be comparable to the SHAPP control, heavy sediment deposition may influence the macroinvertebrate community composition.

Macroinvertebrate Stream Condition Index

LSFR 21.1 had a partially supporting MSCI score of 12 in fall 2018, with all individual metric values being suboptimal (Table 7). The community composition was altered by being smaller, less sensitive, more tolerant of organic pollution/disturbance, and less diverse than what would be expected in a BIOREF stream. There was no substantial change in metric values between this and the station immediately upstream, but the BI increased slightly in LSFR downstream of Sweetwater Branch.

Dominant Macroinvertebrate Taxa

The DMT composition was used to evaluate similarities and differences between LSFR 21.1 and BIOREF conditions in the fall (Table 10). Six DMT were found in common with BIOREF streams. Among those were *Caenis anceps*, *Hyaella azteca*, and Acarina, which were not prevalent at most stations in LSFR. Four of the remaining DMT were absent (2 taxa) or ranked low (2 taxa) at LSFR 21.1. *Maccaffertium mediopunctatum* and *Isonychia bicolor* were not present in the sample, and *Cricotopus/Orthocladus* grp. was reduced; all three of these taxa were commonly missing or ranked low at LSFR stations. However, *Stenelmis* spp. was ranked low at LSFR 21.1, but it was prevalent at most other LSFR sites. This riffle beetle was ranked low at only three stations in LSFR. These same three stations were identified earlier using the SHAPP as being the only stations with both heavy sediment deposition and poor riffle quality. Poor riffle quality due to heavy sediment deposition may have affected *Stenelmis* spp. abundance as DMT. Sediment quantity does not, however, exclude the sediment character or other factors as potential influences on the community composition. The macroinvertebrate community was not similar to those found in BIOREF streams of the EDU.

Water Quality

Although several water quality constituents were notable or exceeded EPA (2000) suggested guidelines at LSFR 21.1 in fall (Table 13), none exceeded WQS (MoDNR 2018c). Discharge (6.7 cfs) was among the lowest in LSFR but slightly higher than upstream due to flow from Sweetwater Branch. Specific conductance (227 μ S/cm), sulfate (12.2 mg/L), and chloride (6.19 mg/L) were among the lower readings of LSFR stations. Turbidity (4.8 NTU), total nitrogen (0.48 mg/L), nitrate+nitrite as N (0.22 mg/L), and total phosphorus (0.050 mg/L) exceeded EPA (2000) guidelines. Turbidity was highest among stations. Ammonia-N (0.031 mg/L) was also detected, but at a low concentration. Sweetwater Branch did not appear to affect the overall water quality of LSFR.

Dissolved Metals

Dissolved metals were notable in the LSFR 21.1 surface water sample (Table 16). Iron (223 µg/L) was present in a much higher concentration than other Fredericktown area stations, but it was nearly equal to station LSFR 21.2 just upstream. Dissolved lead (2.15 µg/L) was near the WQS (MoDNR 2018c) hardness dependent chronic toxicity threshold (2.79 µg/L at a hardness of 110 mg/L as CaCO₃). The manganese (72.1 µg/L) concentration was similar to the upstream LSFR station and higher than most other stations. Dissolved nickel (<0.05 µg/L) was not observed at this station.

Fine Sediment Metals

Total metals were observed in fine sediment samples with several exceeding toxicity thresholds at LSFR 21.1 (Table 19; Figures 7, 9, and 11). Cadmium (0.458 mg/kg) was present below the PEC (4.98 mg/kg), but it was higher than all other stations and the control. The cobalt level (59.1 mg/kg) was much higher than the upstream station, and nearly nine times higher than the Castor River control. Copper (241.0 mg/kg) exceeded the PEC (149.0 mg/kg) by 1.62 times, was nearly ten times higher than the station immediately upstream, and was 30-times that of the Castor River control (Figure 7). Lead (15,500.0 mg/kg) was 121-times higher than the PEC threshold (128.0 mg/kg) and the concentration found immediately upstream, and it was over 980 times higher than the control (Figure 9). Nickel (61.9 mg/kg) exceeded the PEC threshold (48.6 mg/kg) by 1.27 times and was 4-times higher than the upstream station and the control (Figure 11). LSFR 21.1 was the first station (from upstream) in which silver (0.909 mg/kg) was detected. The silver concentration was approximately half of the PEC (2.2 mg/kg). The measures combining cadmium, lead, and zinc ($\sum \text{PEQ}_{\text{Cd, Pb, Zn}} = 121.26$) far exceeded the threshold ($T_{10} \geq 7.92$), and the mean $\text{PEQ}_{\text{metals}}$ (17.84) was also exceeded (mean $\text{PEQ}_{\text{metals}} \geq 1.11$) for all metals combined. The individual lead concentration also exceeded the TSMD site-specific criterion ($T_{10} = 150$ mg/kg) by over 100 fold.

Summary

Several aspects may have played a role in shaping the community composition at LSFR 21.1. LSFR 21.1 had a partially supporting MSCI score, and the DMT assemblage was not similar to BIOREF communities. Overall stream habitat was comparable to the SHAPP control; however, fine sediment covered much of the substrate including riffles, potentially influencing the presence of certain taxa. Water quality analyses did not identify potential causes of aquatic community effects at this station. The dissolved lead concentration was again near, but did not exceed the WQS chronic toxicity threshold, indicating there was an upstream or instream source that could be a contributing factor. Total copper, lead, and nickel concentrations in the benthic sediment sample greatly exceeded their respective PEC thresholds. The amount of fine sediment coverage and metals character associated with the fine sediment may have influenced the ability of this station to support the beneficial use for the protection of WWH. Sweetwater Branch, located immediately upstream of LSFR 21.1, drains Harmony Lake (also known as Mine La Motte Lake) and the immediate watershed in the Northern Madison Unit (OU 1; Figures 2 and 3; Appendix B). Sweetwater Branch is a potential contributor of constituents that may have affected the LSFR 21.1 biological status.

Station LSFR 16.6 – Downstream of Fredericktown City Lake Stream Habitat Assessment

Although stream habitat at LSFR 16.6 reached a 75 percent similarity and was considered comparable to the SHAPP control (Table 5), it was one of the lowest among LSFR stations. Notable features included few velocity depth regimes, moderately heavy sediment deposition, poor riffle quality, little vegetative protection on both banks, and a narrow riparian corridor on the left bank. Banks, however, were very stable. This station is one of three to have heavy sediment deposition and poor riffle quality.

Macroinvertebrate Stream Condition Index

LSFR 16.6 had a partially supporting MSCI score of 12 in fall 2018 (Table 7). All four biological metric values had suboptimal individual scores of 3, which indicate the presence of a smaller, less sensitive, more organic pollution/disturbance tolerant, and less diverse community compared to BIOREF streams. A substantial decrease in TR, EPTT, and SDI, and a notable increase in the BI metric value from the station upstream potentially suggest an organic pollution/disturbance influence that altered the community composition.

Dominant Macroinvertebrate Taxa

The DMT composition was used to evaluate similarities and differences between LSFR 16.6 and BIOREF streams in the fall (Table 10). Four DMT were in common with the BIOREFs. Two of the four taxa (*Caenis latipennis* and Acarina) were prevalent at a majority of stations, and two (*Hyalella azteca* and Acarina) were not found at most stations. Six DMT were absent (3 taxa) or ranked low (3 taxa). *Caenis anceps* was absent for the first time (upstream to downstream); *Maccaffertium mediopunctatum* and *Isonychia bicolor* were also absent at LSFR 16.6 and were consistently rare at LSFR stations. Two of the three remaining taxa that ranked low were prevalent at the majority of stations. *Stenelmis* spp. (a riffle beetle) ranked low at this station but was a DMT at all but three LSFR stations. Interestingly, *Tricorythodes* spp. also ranked low yet was one of the most abundant DMT at all other LSFR stations. The one remaining taxon (*Cricotopus/Orthocladius* grp.) that ranked low was not among DMT at any station.

Water Quality

Several water quality constituents were notable or exceeded EPA (2000) suggested guidelines at LSFR 16.6 in fall (Table 13), but none of the constituents exceeded WQS (MoDNR 2018c). Discharge (4.5 cfs) was lowest among stations below the Fredericktown City Lake dam. Specific conductance (227 μ S/cm), sulfate (11.4 mg/L), and chloride (6.23 mg/L) were similar to, or slightly lower than upstream stations. Turbidity (2.7 NTU), total nitrogen (0.61 mg/L), nitrate+nitrite as N (0.29 mg/L), and total phosphorus (0.049 mg/L) exceeded EPA (2000) guidelines and were generally similar to upstream stations.

Dissolved Metals

Dissolved metals were notable at LSFR 16.6 in fall (Table 16). The iron concentration (14.6 μ g/L) was much lower than in stations upstream of Fredericktown City Lake, but similar to the remaining stations downstream. Dissolved lead (2.92 μ g/L) exceeded the WQS (2018c) chronic toxicity threshold (2.82 μ g/L at a hardness of 111 mg/L as CaCO₃) for the first and only

time in LSFR. Unlike the two stations upstream of Fredericktown City Lake, nickel was detected (0.61 µg/L) at LSFR 16.6.

Fine Sediment Metals

One fine sediment metal was remarkable in the LSFR 16.6 sample (Table 19; Figure 9). Total lead (1520.0 mg/kg) exceeded the PEC threshold (128.0 mg/kg) by nearly 12-times and was over 40-times higher than the Castor River control. However, lead was over 10-fold lower than the concentration observed upstream of Fredericktown City Lake. All other metals were well below threshold concentrations. The mixture of cadmium, lead, and zinc ($\sum \text{PEQ}_{\text{Cd, Pb, Zn}} = 11.97$) exceeded the TMSD threshold ($T_{10} \geq 7.92$), and the mean $\text{PEQ}_{\text{metals}}$ (1.87) exceeded the threshold (mean $\text{PEQ}_{\text{metals}} \geq 1.11$) for all metals combined. The mixture or combination of metals thresholds were exceeded because of the high lead concentration. The individual lead concentration also exceeded the TMSD site-specific criterion ($T_{10} = 150 \text{ mg/kg}$) by over 10-fold.

Summary

Several factors may have contributed to the community composition at LSFR 16.6. This site had a partially supporting MSCI score, and the DMT assemblage was substantially different from the taxa that dominate BIOREF streams. Overall stream habitat was comparable to the SHAPP control; however, features included heavy fine sediment deposition and poor riffle quality, which may have influenced the presence of these taxa. Water quality analyses did not identify potential causes of aquatic community effects at this station, but nutrient concentrations were slightly higher than upstream of Fredericktown City Lake. Dissolved lead exceeded the WQS chronic toxicity threshold (MoDNR 2018c), which may have affected the aquatic community. Nickel was first detected at this site, and total fine sediment lead greatly exceeded the PEC threshold. Heavy sediment deposition, dissolved lead, and total fine sediment lead may have contributed to the ability of the station to support the beneficial use. Both banks were very stable and the sediment did not resemble local bank soil, so the constituents may have been added to the station through discharge from Fredericktown City Lake, located just upstream (Figures 2 and 3; Appendix B).

Station LSFR 16.3 – Downstream of Village Creek

Stream Habitat Assessment

The LSFR 16.3 stream habitat score was 98 percent of the SHAPP control and was considered comparable (Table 5). Notable features at this station included very little vegetative protection and a moderately unstable right bank with nearly 60 percent affected by erosion.

Macroinvertebrate Stream Condition Index

LSFR 16.3 had a partially supporting MSCI score of 12 in fall 2018 (Table 7). All individual metrics had suboptimal values and indicated a macroinvertebrate community with fewer taxa, fewer sensitive taxa, more taxa tolerant of organic pollution/disturbance, and less diversity than occurs at BIOREF streams. However, each of the four LSFR 16.3 biological metrics improved compared to the station immediately upstream.

Dominant Macroinvertebrate Taxa

The LSFR16.3 DMT composition as compared to BIOREF streams is presented in Table 10. Five DMT were found in common with the BIOREF streams. Four of the five taxa were prevalent at most stations, but *Hyaella azteca* was prevalent at this station and only a few others. Five of the remaining DMT were absent (2 taxa) or ranked low (3 taxa) at this station downstream from Village Creek. *Caenis anceps* and *Maccaffertium mediopunctatum* were the only DMT absent from this station. All other DMT were commonly absent or reduced at most other stations in LSFR. The macroinvertebrate community was not similar to those found in BIOREF streams of the EDU.

Water Quality

Several water quality constituents were notable or exceeded EPA (2000) suggested guidelines at LSFR 16.3 in fall (Table 13), but none of the constituents exceeded WQS (MoDNR 2018c). Discharge (7.7 cfs) increased from upstream stations by approximately 3 cfs due to flow from Village Creek. Specific conductance (287 $\mu\text{S}/\text{cm}$) and chloride (6.45 mg/L) were among the lower LSFR values. Sulfate (17.1 mg/L) increased by nearly 6 mg/L from the LSFR 16.6 station. Turbidity (2.2 NTU), total nitrogen (0.59 mg/L), nitrate+nitrite as N (0.35 mg/L), and total phosphorus (0.060 mg/L) exceeded EPA (2000) guidelines. There was a slight increase in nitrate+nitrite as N and total phosphorus downstream of the Village Creek confluence. The ammonia as N concentration was below laboratory detection (<0.02 mg/L).

Dissolved Metals

Dissolved lead was notable at LSFR 16.3 in fall (Table 16). Dissolved lead (2.35 $\mu\text{g}/\text{L}$) was near the WQS (MoDNR 2018c) chronic toxicity threshold (3.76 $\mu\text{g}/\text{L}$ at a hardness of 145 mg/L as CaCO_3). The dissolved lead concentration was slightly lower than the station immediately upstream and higher than Village Creek samples.

Fine Sediment Metals

One fine sediment metal was notable in LSFR 16.3A and LSFR 16.3B duplicate samples (Table 19; Figure 9). Lead at LSFR 16.3A and LSFR 16.3 B (703.0 mg/kg and 1190.0 mg/kg, respectively) exceeded the PEC threshold (128.0 mg/kg) by 5.49 and 9.30 times, respectively. The difference between duplicate samples may be related to a composite sampling of an unequally distributed sediment and laboratory subsampling of that composited material (See Section 3.3). The mean of the duplicates (946.5 mg/kg) was nearly 47 percent (RPD) lower than the level observed upstream, but it was over 25-times higher than the Castor River control. All other metals were well below PEC thresholds and were generally similar to those observed upstream. In LSFR 16.3A, the mixture or combination of cadmium, lead, and zinc ($\sum\text{PEQ}_{\text{Cd, Pb, Zn}} = 5.57$) did not exceed the threshold ($T_{10} \geq 7.92$); however, the mean $\text{PEQ}_{\text{metals}}$ (0.92) was near the threshold (mean $\text{PEQ}_{\text{metals}} \geq 1.11$) for all metals combined, due mainly to the elevated lead concentration. In LSFR 16.3B, the cadmium, lead, and zinc ($\sum\text{PEQ}_{\text{Cd, Pb, Zn}} = 9.42$) mixture exceeded the threshold ($T_{10} \geq 7.92$), and the mean $\text{PEQ}_{\text{metals}}$ (1.54) exceeded the threshold (mean $\text{PEQ}_{\text{metals}} \geq 1.11$) for all metals combined, due again mainly to the elevated lead concentration. Both duplicate lead concentrations exceeded the TSMD site-specific criterion ($T_{10} = 150$ mg/kg) by a range from nearly 5- to 8-fold.

Summary

LSFR 16.3 had a partially supporting MSCI score, and the DMT composition was substantially different than from that which is found in BIOREF streams. Overall stream habitat was very comparable to the SHAPP control with among the highest scores and is not likely to have negatively affected the aquatic community. Water quality analyses did not identify constituents that influenced the community. Dissolved lead was near the chronic toxicity threshold WQS (MoDNR 2018c), which identified it as a potential source to alter the community composition. Although the dissolved lead concentration was near the WQS threshold, it was lower than the station immediately upstream. Total fine sediment lead greatly exceeded its PEC threshold and was a potential source for decreasing the ability of this station to support the beneficial use. Here again, the level of lead was lower than the station upstream. LSFR 16.3 is located immediately downstream from the Village Creek confluence (Figures 2 and 3; Appendix B), but dissolved metals and sediment metals analysis suggested it was not an obvious contributor of metals to LSFR during this study.

Station LSFR 16.0 – Downstream of Saline Creek

Stream Habitat Assessment

The LSFR 16.0 stream habitat score was the highest among LSFR stations. It was slightly higher than the SHAPP control and was considered comparable (Table 5). In spite of its comparable status, the station had heavy sediment deposition and little vegetative protection. Banks were very stable, so sediment deposition likely did not come from the immediate vicinity.

Macroinvertebrate Stream Condition Index

LSFR 16.0 had a partially supporting MSCI score of 14 in fall 2018 (Table 7). Of the four biological metrics used to calculate the MSCI, only SDI had an optimal individual metric score of 5. These metrics indicated LSFR 16.0 had fewer taxa, fewer sensitive taxa, and a macroinvertebrate community that was more tolerant of organic pollution/disturbance. However, it was as diverse as BIOREF streams, one of only two stations in LSFR with optimal diversity.

Dominant Macroinvertebrate Taxa

The LSFR 16.0 DMT composition as compared to BIOREF streams is presented in Table 10. Four DMT were in common with BIOREF streams. All four were prevalent at most LSFR stations. Six of the DMT remaining were absent (3 taxa) or ranked low (3 taxa) at this station. *Caenis anceps*, *Maccaffertium mediopunctatum*, and *Isonychia bicolor* were absent from the sample. Most of the remaining DMT ranked low or were absent from the majority of LSFR stations, including *Hyaella azteca*, which ranked low at this station.

Water Quality

Several water quality constituents were notable or exceeded EPA (2000) suggested guidelines at LSFR 16.0 in fall (Table 13), but none exceeded WQS (MoDNR 2018c). Discharge (12.4 cfs) increased by nearly two-fold compared to upstream stations. Specific conductance (379 μ S/cm), sulfate (38.6 mg/L), and chloride (11.4 mg/L) all were much higher than LSFR 16.3 and were among the higher LSFR readings. Total nitrogen (1.65 mg/L), nitrate+nitrite as N (1.57 mg/L), and total phosphorus (0.19 mg/L) exceeded EPA (2000) guidelines and were the highest readings

among LSFR stations. Turbidity also exceeded EPA (2000) guidelines at LSFR 16.0, but it was one of the lower values. Ammonia as N (0.031 mg/L) was detected at a low concentration.

Dissolved Metals

Several dissolved metals were present at LSFR 16.0 in fall (Table 16). This was the first station in LSFR (upstream to downstream) to contain cobalt (2.54 µg/L). Lead (1.60 µg/L) was observed in a lower concentration than all stations upstream. The dissolved nickel (30.3 µg/L) concentration was nearly 50-times higher at LSFR 16.0 than any upstream LSFR station and was approximately one-third of the WQS (MoDNR 2018c) chronic toxicity threshold (89.91 µg/L at hardness 191 mg/L as CaCO₃). Zinc (3.18 µg/L) was observed at a low concentration, but it was over two-times higher than any station upstream.

Fine Sediment Metals

One fine sediment metal was observed at a notable level at LSFR 16.0 (Table 19; Figure 9). Lead (741.0 mg/kg) exceeded the PEC threshold (128.0 mg/kg) by 5.79 times and was over 19-times higher than the Castor River control. Lead at LSFR 16.0 was approximately 24 percent (RPD) lower than the average of the duplicate lead samples upstream. Although all other metals were well below thresholds, some were slightly higher than the station upstream. Cadmium, lead, and zinc ($\sum \text{PEQ}_{\text{Cd, Pb, Zn}} = 5.92$) combined did not exceed the threshold ($T_{10} \geq 7.92$); however, the mean $\text{PEQ}_{\text{metals}}$ (1.14) exceed the threshold (mean $\text{PEQ}_{\text{metals}} \geq 1.11$) for all metals combined, due mainly to the elevated lead level. The individual lead concentration also exceeded the TSMD site-specific criterion ($T_{10} = 150 \text{ mg/kg}$) by over 5-times. Lead in fine sediment exceeded the toxicity threshold, above which toxic effects may occur within the macroinvertebrate community.

Summary

LSFR 16.0 attained a partially supporting MSCI score, and the DMT assemblage was unlike BIOREF streams of the EDU. Overall stream habitat was comparable to the SHAPP control with the highest score among LSFR stations and was not an obvious contributor to the status of the community. Several water quality constituents were slightly elevated compared to other LSFR stations upstream or downstream, which are likely related to discharge from the Fredericktown WWTF located approximately 0.5 mile upstream in SC; however, none were obvious contributors to the community composition. Dissolved lead was present below the PEC threshold and lower than all upstream stations. Dissolved cobalt was observed for the first time in LSFR, and dissolved nickel was observed at the highest concentration among LSFR stations at approximately half of the WQS (MoDNR 2018c). Dissolved cobalt and nickel appear to have been contributed to LSFR by Saline Creek. Dissolved nickel was present in decreasing concentrations from LSFR 16.0 to LSFR 0.4 near the confluence with St. Francis River. Both dissolved cobalt and nickel can be traced back upstream in Saline Creek to the station immediately downstream from Unnamed Tributary, which drains a large tailings pond south of Saline Creek (See SC 1.3; Appendix B). The presence of dissolved metals shows the potential to exceed WQS thresholds. Total lead in fine sediment greatly exceeded the PEC, which suggests it may have contributed to the altered community composition. The total lead concentration was lower than the station immediately upstream, suggesting the source for fine sediment metals may

not be from Saline Creek. Saline Creek was an apparent source for additional dissolved metals, but not the obvious source for the fine sediment metals that may have influenced the community composition and the stream's ability to support the WWH beneficial use (Figures 2 and 3; Appendix B – LSFR).

Station LSFR 13.7 – Downstream of Spiva Branch

Stream Habitat Assessment

LSFR 13.7 had the lowest stream habitat assessment score in this study and, with a 57 percent similarity, was not comparable to the SHAPP control (Table 5). The score was much lower due to features such as poor epifaunal substrate, nearly complete embeddedness and sediment coverage, very poor riffle quality, very little vegetative protection, and a narrow riparian corridor on the left bank. This station is one of three (LSFR 21.1, LSFR 16.6, and LSFR 13.7) to have heavy sediment deposition and poor riffle quality. The fine sediment was homogeneous in size (≤ 2.0 mm) and color (gray), and it had the general appearance of mine-related material. Banks were stable, and no local mine-related influences were apparent adjacent to the stream.

Macroinvertebrate Stream Condition Index

LSFR 13.7 had a partially supporting MSCI score of 12 in fall 2018 (Table 7). All individual metric values attained suboptimal scores of 3 at this station. Additionally, each metric value was the farthest from its respective optimal scoring range among LSFR sites. This station had the smallest, least sensitive, most tolerant of organic pollution/disturbance, and least diverse community of all LSFR stations. Compared to LSFR 16.0, the station immediately upstream, the number of taxa decreased by 25, EPT taxa decreased by 5, the BI value increased by 1.1, and SDI was 1.57 lower.

Dominant Macroinvertebrate Taxa

The LSFR 13.7 DMT composition comparison with BIOREF streams is presented in Table 10. Five DMT were found in common with the BIOREF streams; among those were *Hyalella azteca* and Acarina, which were rarely in common DMT in LSFR. Five of the DMT were absent (4 taxa, the highest number of absences) or ranked low (1 taxon) at this station downstream of Spiva Branch. *Caenis anceps*, *Maccaffertium mediopunctatum*, and *Isonychia bicolor* were absent at this site and were rarely observed at other stations. The riffle beetle *Stenelmis* spp. ranked low at this station, yet it was among the more prevalent DMT among most stations. As mentioned, LSFR 13.7 was one of only three stations (LSFR 21.1, LSFR 16.6, LSFR 13.7) identified by the SHAPP as having heavy fine sediment deposition and poor riffle quality; all three had reduced riffle beetle populations.

Water Quality

Several water quality constituents were notable, but none exceeded WQS (MoDNR 2018c) at LSFR 13.7 (Table 13). Discharge (13.1 cfs) increased slightly due to increased watershed size and discharge from Spiva Branch. Although specific conductance (394 $\mu\text{S}/\text{cm}$) was highest among stations, sulfate (36.0 mg/L), and chloride (11.5 mg/L) were similar to the nearest upstream station. Turbidity (3.7 NTU) was among the higher concentrations, perhaps due to additional particulate input from increased discharge. Total nitrogen (1.47 mg/L), nitrate+nitrite

as N (1.32 mg/L), and total phosphorus (0.16 mg/L) exceeded EPA (2000) suggested guidelines, but they were slightly lower than the station immediately upstream. Ammonia as N (0.048 mg/L) was observed at a slightly higher concentration than immediately upstream.

Dissolved Metals

Several dissolved metals were notable at LSFR 13.7 (Table 16). Unlike the station immediately upstream, dissolved cobalt (<1 µg/L) was not detected at LSFR 13.7. Dissolved lead (2.75 µg/L) was observed at over half of the WQS (MoDNR 2018c) chronic toxicity threshold (5.19 µg/L at hardness 196 mg/L as CaCO₃). Manganese (71.9 µg/L) increased from the station immediately upstream. Dissolved nickel (13.5 µg/L) decreased by nearly 77 percent (RPD) from the nearest upstream station.

Fine Sediment Metals

Several fine sediment metals concentrations were notable and exceeded thresholds at LSFR 13.7 (Table 19; Figures 7, 9, and 11). Cobalt (75.2 mg/kg) more than doubled from upstream and was over 11-times higher than the Castor River control. Copper (25.6 mg/kg) was well below the PEC threshold (149.0 mg/kg), but it increased slightly from upstream and was approximately 3-times higher than the control (Figure 7). Lead (678.0 mg/kg) exceeded the PEC threshold (128.0 mg/kg) by over 5-times and was approximately 18-times higher than the control, but it was slightly lower than the station immediately upstream (Figure 9). Nickel (89.0 mg) increased sharply from the preceding four stations upstream, exceeding the PEC threshold (48.6 mg/kg) by 1.83-times and the control by nearly 6-times (Figure 11). The measure combining cadmium, lead, and zinc ($\sum \text{PEQ}_{\text{Cd, Pb, Zn}} = 5.41$) did not exceed the threshold ($T_{10} \geq 7.92$); however, the mean $\text{PEQ}_{\text{metals}}$ (1.14) exceeded the threshold (mean $\text{PEQ}_{\text{metals}} \geq 1.11$) for all metals combined. The individual lead concentration also exceeded the TSMD site-specific criterion ($T_{10} = 150 \text{ mg/kg}$) by over 4-fold.

Summary

Several aspects may have played a role in shaping the LSFR 13.7 macroinvertebrate community composition. LSFR 13.7 had a partially supporting MSCI score and a DMT assemblage that was substantially different from the communities found in BIOREF streams. Stream habitat was not comparable to the SHAPP control, due to a nearly complete coverage of the stream bottom by fine sediment. The fine sediment was uniform in color (gray) and size (<2.0 mm) and was similar in appearance to mine tailings/chat. Water quality constituents were not an obvious influence on the community, but nutrients were likely contributed far upstream by Saline Creek (LSFR 16.0) and the Fredericktown WWTF. Dissolved lead and copper increased, while nickel and cobalt decreased from the station immediately upstream; all were below WQS threshold concentrations where defined. Total fine sediment lead and nickel exceeded individual PEC thresholds, while copper and cobalt were added at this point as well. The mixture of all metals combined also exceeded the mean threshold, as did the TSMD site-specific threshold for lead. The amount of fine sediment coverage and the total fine sediment metals may have negatively affected the macroinvertebrate community composition LSFR 13.7. There were no obvious local sources for the fine sediment adjacent to the stream such as tailings/chat piles. The banks were stable, and the sediment did not look like bank soil. The stream was wider and flow was slower than most

other LSFR stations, which may account for the increased deposition of fine sediment at this point. This massive lens of metals-rich fine sediment appears to be a pulse of mine tailings/chat from upstream sources that may include Spiva Branch and other tributaries upstream (Figures 2 and 3; Appendix B).

Station LSFR 13.2 – At the Mill Creek Confluence

Fine Sediment Metals (only)

Several fine sediment related metals were notable and exceeded thresholds in the long pool and bar downstream of U.S. Highway 67 (Table 19; Figures 5, 7, 9, and 11). The LSFR 13.2 arsenic level (33.50 mg/kg) exceeded the PEC threshold (33.0 mg/kg) by 1.01 times, and was over 2-times higher than the station immediately upstream and the Castor River control (Figure 5). Cobalt (157.0 mg/kg) increased more than 2-fold over the station upstream. Copper (37.70 mg/kg) was well below the PEC threshold (149.0 mg/kg), but it increased slightly from upstream and was higher than the control (Figure 7). Lead (1030.0 mg/kg) exceeded the PEC threshold (128.0 mg/kg) by over 8-times, was approximately 1.5-times higher than upstream, and approximately 27-times higher than the control (Figure 9). Nickel (180.0 mg/kg) exceeded the PEC threshold (48.6 mg/kg) by 3.7-times, was over 2-fold higher than upstream, and over 11-times higher than the control (Figure 11). Silver (0.646 mg/kg) did not exceed the PEC threshold (2.2 mg/kg), but it was observed in the second highest concentration among LSFR stations. Silver was approximately one-third of the threshold and over twice that of the station upstream. The combination of cadmium, lead, and zinc ($\sum \text{PEQ}_{\text{Cd, Pb, Zn}} = 8.23$) exceeded the threshold ($T_{10} \geq 7.92$), and the mean $\text{PEQ}_{\text{metals}}$ (1.93) also exceeded the threshold (mean $\text{PEQ}_{\text{metals}} \geq 1.11$) for all metals combined. The individual lead concentration also exceeded the TSMD site-specific criterion ($T_{10} = 150$ mg/kg) by nearly 7-fold.

Summary

Fine sediment at LSFR 13.2 (at the Mill Creek confluence) was collected near the end of the long bridge pool downstream of Old Highway 67 (Figures 2 and 3). The benthic fine sediment was similar in color and size to the substrate at LSFR 13.7, approximately 0.25 miles upstream. Interestingly, total arsenic, lead, and nickel levels exceeded individual PECs and were much higher than LSFR 13.7 (Table 19, Figures 5, 9, and 11). Cobalt, copper, and silver were apparently also added at this point in LSFR. Both measurements that account for the mixture or combination of metals thresholds were also exceeded. More heavy metals were found at this station than at all other LSFR stations, and in higher concentrations. Benthic substrate at this site may be associated with a pulse of mine-related fine sediment from upstream, discharge from Mill Creek, or both (Figures 2 and 3; Appendix B).

Station LSFR 13.0 – Downstream of Mill Creek

Stream Habitat Assessment

The LSFR 13.0 stream habitat score was 91 percent of the SHAPP control and was considered comparable (Table 5). Notable features include heavy sediment deposition and little vegetative protection on both banks. Despite the vegetative protection status, the banks were very stable.

Macroinvertebrate Stream Condition Index

LSFR 13.0 had a partially supporting MSCI score of 12 in fall 2018 (Table 7). All metric values had suboptimal individual scores of 3. The community was smaller, less sensitive, more tolerant of organic pollution/disturbance, and less diverse compared to BIOREF streams. Although the MSCI score did not change, metric values increased (BI decreased) compared to LSFR 13.7 immediately upstream.

Dominant Macroinvertebrate Taxa

The LSFR 13.0 DMT composition comparison with BIOREF streams is presented in Table 10. This station contained only three DMT in common with BIOREF streams; all three were commonly prevalent in LSFR stations. Seven DMT were absent (1 taxon) or ranked low (6 taxa) at this station downstream from Mill Creek. *Maccaffertium mediopunctatum* was present for the first and only time in LSFR but was ranked low. Interestingly, *Tanytarsus* spp., which was found in common with BIOREF streams at all other LSFR stations, was ranked low only at this site. Most of the remaining DMT that ranked low were commonly rare in the majority of stations.

Water Quality

Several water quality constituents were notable at LSFR 13.0; however, none exceeded WQS (MoDNR 2018c; Table 13). Discharge (19.4 cfs) increased by over 6 cfs compared to upstream stations due to the addition of Mill Creek discharge. Specific conductance (365 μ S/cm), sulfate (25.5 mg/L), and chloride (9.47 mg/L) were slightly lower than the two preceding stations upstream (LSFR 13.7 and LSFR 16.0). Although turbidity (2.9 NTU), total nitrogen (1.15 mg/L), nitrate+nitrite as N (1.01 mg/L), and total phosphorus (0.10 mg/L) exceeded EPA (2000) guidelines, they were slightly lower than immediately upstream. Conversely, ammonia-N (0.054 mg/L) was detected in the second highest concentration among LSFR stations.

Dissolved Metals

Dissolved metals were present at LSFR 13.0 in fall (Table 16). Cobalt (with an estimated value of 1.08 μ g/L) was detected at LSFR 13.0, which was the second of two locations in LSFR (cobalt was also present at LSFR 16.0). Dissolved lead (2.07 μ g/L) decreased slightly from upstream, but it remained nearly half of the WQS (MoDNR 2018c) chronic toxicity threshold (4.91 μ g/L at hardness 186 mg/L as CaCO_3) and was similar to concentrations in the most upstream stations. Manganese (119 μ g/L) was present in the highest concentration among LSFR stations. Nickel (7.80 μ g/L) was observed at approximately half of the concentration found immediately upstream.

Fine Sediment Metals

Several fine sediment metals concentrations were notable and exceeded potentially toxic thresholds at LSFR 13.0 (Table 19; Figures 5, 9, and 11). Total arsenic (19.2 mg/kg) decreased by over 50 percent (RPD) from the high observed upstream at LSFR 13.2 and did not exceed the PEC threshold (33.0 mg/kg). The LSFR 13.0 arsenic concentration was roughly similar to the level observed at the Castor River control (Figure 5). Cobalt (67.3 mg/kg) decreased by over two fold, while copper (29.40 mg/kg) was well below the PEC threshold (149.0 mg/kg) and was less than half of the level observed at the station immediately upstream (Figure 7). Total lead

(1080.0 mg/kg), however, exceeded the PEC threshold (128.0 mg/kg) by 8.44 times, remained similar to the level observed upstream, and was approximately 29-times higher than the control (Figure 9). Nickel (81.6 mg/kg) exceeded the PEC threshold (48.6 mg/kg) by 1.68 times, was approximately 5-times higher than the control, but was less than half compared to upstream. Silver (<0.250 mg/kg) was again not detected in LSFR. The mixture of cadmium, lead, and zinc ($\Sigma\text{PEQ}_{\text{Cd, Pb, Zn}} = 8.61$) exceeded the threshold ($T_{10} \geq 7.92$), and the mean $\text{PEQ}_{\text{metals}}$ (1.58) exceeded the normalized toxicity threshold (mean $\text{PEQ}_{\text{metals}} \geq 1.11$) for all metals combined. Both were elevated mainly due to the very high lead level. The individual lead level exceeded the TSMD site-specific criterion ($T_{10} = 150$ mg/kg) by over 7-fold.

Summary

LSFR 13.0 had a partially supporting MSCI score with a DMT assemblage that was substantially different from BIOREF stream communities of the EDU. Stream habitat was comparable to the SHAPP control; however, large deposits of fine sediment covered much of the stream bottom. Water quality constituents were not an obvious influence on the community, but nutrients, sulfate, and chloride were likely remnant contributions from Saline Creek. Dissolved cobalt was detected for the second time in LSFR, but the lead concentration decreased to below the WQS chronic toxicity concentration. Lead and nickel levels both were lower than immediately upstream. Total fine sediment lead and nickel remained above PECs, while arsenic, cobalt, copper, and silver decreased from levels observed upstream. Heavy coverage of fine sediment with a high concentration of heavy metals was a potential contributor to the altered community composition at LSFR 13.0. Sources for these influences may be from upstream, Mill Creek, or both (Figures 2 and 3; Appendix B).

Station LSFR 10.4 – Downstream of Plum Creek (at Thompson Ford Conservation Access) *Stream Habitat Assessment*

Stream habitat at LSFR 10.4 was comparable to the SHAPP control with a 97 percent similarity (Table 5). Features that negatively affected the score included heavy sediment deposition and little vegetative protection. Both banks were stable.

Macroinvertebrate Stream Condition Index

LSFR 10.4 was the first LSFR station (from upstream to downstream) to attain a fully supporting MSCI score of 16 in fall 2018 (Table 7). Two of the four metric values had suboptimal scores. The TR and SDI metrics each had scores of 3, and the EPTT and BI metrics were within the optimal range, each with a score of 5. This station had slightly fewer taxa, and the community was less diverse and evenly distributed than BIOREF streams, but there were more sensitive taxa and fewer that were tolerant of organic pollution/disturbance. The community at LSFR 10.4 had substantially more sensitive taxa and fewer taxa tolerant of organic pollution/disturbance than all other upstream stations.

Dominant Macroinvertebrate Taxa

The LSFR 10.4 DMT composition comparison with BIOREF streams is presented in Table 10. Five DMT were found in common with BIOREF streams. *Caenis anceps* again was present after being absent from the five stations upstream, and *Tanytarsus* spp. was abundant after a decline

upstream. Five DMT were absent (1 taxon) or ranked low (4 taxa) at LSFR 10.4. Despite the higher number of EPT, *Maccaffertium mediopunctatum* was absent from this station, as it was from all except LSFR 13.0. The DMT that ranked low were also rare at most other LSFR stations.

Water Quality

Several water quality constituents were notable or exceeded EPA (2000) suggested guidelines at LSFR 10.4 in fall (Table 13); however, none of the constituents exceeded WQS (MoDNR 2018c). Discharge (14.9 cfs) decreased by nearly 5 cfs from the nearest station upstream. Specific conductance (352 $\mu\text{S}/\text{cm}$), sulfate (25.1 mg/L), and chloride (8.68 mg/L) decreased slightly from immediately upstream. Turbidity (2.5 NTU), total nitrogen (0.95 mg/L), nitrate+nitrite as N (0.82 mg/L), and total phosphorus (0.078 mg/L) exceeded EPA (2000) guidelines. The ammonia-N concentration was below laboratory detection (<0.02 mg/L). All of these constituents were present in lower concentrations than the preceding upstream station.

Dissolved Metals

Dissolved metals were observed in low concentrations at LSFR 10.4 in fall (Table 16). Cobalt (<1 $\mu\text{g}/\text{L}$) again was not detected. Dissolved lead (1.51 $\mu\text{g}/\text{L}$) was observed in a lower concentration than any of the upstream LSFR stations. Manganese (35.3 $\mu\text{g}/\text{L}$) decreased nearly three-fold from the station upstream, and zinc (1.17 $\mu\text{g}/\text{L}$) was detected in a very low concentration.

Fine Sediment Metals

Fine sediment metals were present at LSFR 10.4 (Table 19; Figures 5, 9, and 11). Arsenic (10.10 mg/kg) decreased by nearly half from immediately upstream and was again below the PEC threshold (Figure 5). Although the lead level (440.0 mg/kg) was less than half of the station immediately upstream, it exceeded the PEC threshold (128.0 mg/kg) by over 3-times and was nearly 12-fold higher than the Castor River control (Figure 9). Likewise, the nickel concentration (53.1 mg/kg) decreased by over 42 percent (RPD) from upstream, but it exceeded the PEC threshold (48.6 mg/kg) by 1.09 times and was over 3-times higher than the control (Figure 11). The combination of cadmium, lead, and zinc ($\sum\text{PEQ}_{\text{Cd, Pb, Zn}} = 3.55$) did not exceed the threshold ($T_{10} \geq 7.92$), and the mean $\text{PEQ}_{\text{metals}}$ (0.72) did not exceed the threshold (mean $\text{PEQ}_{\text{metals}} \geq 1.11$) for all metals combined. The individual lead level also exceeded the TSMD site-specific criterion ($T_{10} = 150$ mg/kg) by nearly 3-fold.

Summary

LSFR 10.4 had a fully supporting MSCI score of 16. This was the first station (upstream to downstream) with a fully supporting score. The community was more sensitive and less tolerant of organic pollution/disturbance than all other LSFR stations upstream. However, the DMT assemblage was not similar to those found in BIOREF streams; taxa that were missing or ranked low at LSFR 10.4 were also rare at the majority of LSFR stations. Stream habitat was very comparable to the SHAPP control, although fine sediment coverage was prevalent in areas of this station. Water quality did not obviously influence the community composition, and nutrient concentrations decreased from the station upstream. Dissolved metals concentrations were all

below WQS chronic toxicity thresholds (MoDNR 2018c). Fine sediment lead and nickel remained above PEC thresholds, but levels were much lower than at the station immediately upstream and all but the most upstream station. The amount of fine sediment coverage and metals character may have influenced the community composition at LSFR 10.4, but not enough to substantially lower the support status. Aspects used in this study suggest the relatively high quality community at LSFR 10.4 is not presently exposed to influences that substantially affected all other LSFR stations upstream. Whether influences have not yet reached this point, or have move past over time is not known.

Station LSFR 3.0 – Downstream of Baptist Camp Stream Habitat Assessment

The LSFR 3.0 stream habitat score was slightly higher than the SHAPP control and was considered comparable (Table 5). The only notable feature was very little vegetative protection, as was seen at all LSFR stations as well as the SHAPP control. Banks were very stable. This was one of only two stations with a score at least as high as the SHAPP control.

Macroinvertebrate Stream Condition Index

LSFR 3.0 had a fully supporting MSCI score of 16 in fall 2018 (Table 7). Although this station reached fully supporting status, the individual TR and SDI metric values received suboptimal metric scores of 3. The EPTT and BI metrics were within the optimal range, each with a score of 5. This station had a macroinvertebrate community with fewer taxa that was less diverse and evenly distributed than BIOREF streams. However, it had a similar number of sensitive taxa that were intolerant of organic pollution/disturbance. LSFR 3.0 had higher taxa richness than all LSFR stations upstream, and the number of EPT taxa was among the highest.

Dominant Macroinvertebrate Taxa

The LSFR 3.0 DMT composition comparison with BIOREF streams is presented in Table 10. Four of the 10 DMT were in common with the BIOREF DMT. These four taxa were prevalent at the majority of stations. Six of the DMT were absent (1 taxon) or ranked low (5 taxa) at this station. *Maccaffertium mediopunctatum* was the only BIOREF DMT absent from the sample, as it was at almost all stations. *Caenis anceps* ranked low, after being found in common at the station immediately upstream. The four remaining DMT that ranked low at LSFR 3.0 also ranked low at the majority of LSFR stations.

Water Quality

Several water quality constituents were notable, but none exceeded WQS (MoDNR 2018c; Table 13). Discharge (39.4 cfs) increased by over two-fold from the station immediately upstream. Specific conductance (335 μ S/cm), sulfate (19.7 mg/L), and chloride (8.21 mg/L) decreased from upstream stations. Turbidity (3.8 NTU), total nitrogen (0.73 mg/L), nitrate+nitrite as N (0.54 mg/L), and total phosphorus (0.065 mg/L) exceeded EPA (2000) guidelines. All constituents but turbidity were lower than the four stations upstream from LSFR 16.0 to LSFR 10.4. This station had the highest ammonia-N (0.073 mg/L) concentration of all LSFR sites, but it was well below the chronic WQS threshold (MoDNR 2018c).

Dissolved Metals

Fall 2018 LSFR 3.0 dissolved metals results are presented in Table 16. Cobalt ($<1 \mu\text{g/L}$) was again not detected. The dissolved lead ($1.46 \mu\text{g/L}$) concentration was lower than any of the upstream LSFR stations. Nickel ($1.43 \mu\text{g/L}$) was present, but in less than half the concentration found immediately upstream. Most dissolved metals were observed in lower concentrations at this station than all stations upstream.

Fine Sediment Metals

Fine sediment metals were notable at LSFR 3.0 (Table 19; Figures 9 and 11). Lead (121 mg/kg) was elevated at 95 percent of the PEC and was approximately 3-times higher than the Castor River control (Figure 9). However, the lead level was more than 3-times lower than the level immediately upstream. Nickel (31.0 mg/kg) was present below the PEC (48.6 mg/kg), but approximately twice that of the control (Figure 11). As a result, the mixture of metals did not exceed thresholds for cadmium, lead, and zinc ($\sum \text{PEQ}_{\text{Cd, Pb, Zn}} = 1.00$), did not exceed the threshold ($T_{10} \geq 7.92$), and the mean $\text{PEQ}_{\text{metals}}$ (0.26) did not exceed the threshold (mean $\text{PEQ}_{\text{metals}} \geq 1.11$) for all metals combined. The individual lead level did not exceed the TSMD site-specific criterion ($T_{10} = 150 \text{ mg/kg}$).

Summary

LSFR 3.0 attained a fully supporting MSCI score, with among the largest, most sensitive and least tolerant of organic pollution/disturbance communities to this point in LSFR. However, the community was still lacking DMT that were also rarely prevalent at most upstream stations. Stream habitat was very comparable to the SHAPP control, with less fine sediment coverage than most stations. Water quality constituents did not obviously influence the community composition, despite substantial inflow from Barnes (2nd order) and Chapel (3rd order) creeks, as well as a tributary (1st order) that entered at Baptist Camp. Dissolved metals concentrations did not exceed WQS chronic toxicity thresholds (MoDNR 2018c) and were similar to or lower than those immediately upstream, including nickel that was apparently added to LSFR upstream at Saline Creek. Fine sediment metals levels were well below PEC thresholds and were either lower than immediately upstream or not detected. Aspects of this study did not identify influences that would negatively affect the community composition. Moreover, the biological metrics indicated the presence of a relatively high quality community that is not exposed to substantial influences that have affected upstream stations. It is unclear whether influences that are affecting upstream stations have not yet reached this station, or whether substantial influences were present in the past and have since moved from this station. The implications of either scenario are a problem for this location in LSFR or points downstream.

Station LSFR 0.4 – Downstream LSFR/Upstream of St. Francis River Confluence ***Stream Habitat Assessment***

The physical habitat condition was evaluated by comparing features between LSFR 0.4 and the SHAPP control (Table 5). Although the station was comparable to the SHAPP control with a 76 percent similarity, it was one of the lower scores in LSFR. The lower score was due to features such as very heavy sediment deposition, very little vegetative protection, and a very narrow riparian corridor. The left bank was stable, but the right bank was moderately stable with nearly

30 percent affected by erosion. Fine sediment observed on the substrate had the appearance of bank soil, as opposed to the material observed at many upstream stations.

Macroinvertebrate Stream Condition Index

LSFR 0.4 had a fully supporting MSCI score of 18 in fall 2018 (Table 7), which was the highest observed among all LSFR stations. The LSFR 0.4 TR value (85 taxa) was the only metric to have a suboptimal score at this site and was only 2 taxa away from having an optimal score. The EPTT, BI, and SDI metrics each received scores of 5. Biological metrics described a community that was slightly smaller than BIOREF streams, but with a similar number of sensitive taxa and taxa tolerant of organic pollution/disturbance, as well as equal in diversity and evenness. The community at LSFR 0.4 was among the largest and most sensitive observed in LSFR, equaled only by the station immediately upstream. LSFR 0.4 had the fewest taxa tolerant of organic pollution/disturbance and the most diverse community among all stations.

Dominant Macroinvertebrate Taxa

The LSFR 0.4 DMT composition comparison with BIOREF streams is presented in Table 10. Four DMT were found in common with BIOREF streams. All four DMT were prevalent at most other stations. Six of the DMT were absent (3 taxa) or ranked low (3 taxa) at this station. *Caenis anceps* and *Maccaffertium mediopunctatum* again were absent from this station. *Hyaella azteca* was also absent from this station, which is notable because they were present in all other LSFR sites upstream.

Water Quality

Several water quality constituents were notable, but none exceeded WQS (MoDNR 2018c) at LSFR 0.4 (Table 13). Discharge (32.2 cfs) decreased by approximately 6 cfs from the nearest upstream station. Specific conductance (323 $\mu\text{S}/\text{cm}$), sulfate (18.1 mg/L), and chloride (7.57 mg/L) decreased from upstream. Turbidity (2.7 NTU), total nitrogen (0.56 mg/L), nitrate+nitrite as N (0.41 mg/L), and total phosphorus (0.66 mg/L) exceeded EPA (2000) guidelines; however, they decreased to levels observed well upstream of the Saline Creek confluence. The ammonia-N concentration was below laboratory detection (<0.02 mg/L).

Dissolved Metals

Dissolved metals were present in low concentrations at LSFR 0.4 in fall (Table 16). Cobalt (<1 $\mu\text{g}/\text{L}$) was again not detected. Dissolved lead (1.66 $\mu\text{g}/\text{L}$) was again among the lower concentrations in LSFR stations. Nickel (1.13 $\mu\text{g}/\text{L}$) was present in the lowest concentration among LSFR sites downstream of Village Creek (downstream of LSFR 16.3). None of the dissolved metals exceeded WQS chronic toxicity thresholds (MoDNR 2018c).

Fine Sediment Metals

Fine sediment metals were present at LSFR 0.4 (Table 19; Figures 9 and 11). Total lead (96.1 mg/kg) was much lower than the PEC threshold (128 mg/kg), approximately 23 percent (RPD) lower than the station immediately upstream, and more than twice the level of the control (Figure 9). Nickel (35.5 mg/kg) was well below the PEC threshold (48.6 mg/kg), similar to the

station immediately upstream, and approximately twice that of the Castor River control. As a result, the mixture of metals did not exceed thresholds for cadmium, lead, and zinc ($\sum \text{PEQ}_{\text{Cd, Pb, Zn}} = 0.80$), did not exceed the threshold ($T_{10} \geq 7.92$), and the mean $\text{PEQ}_{\text{metals}}$ (0.25) did not exceed the threshold (mean $\text{PEQ}_{\text{metals}} \geq 1.11$) for all metals combined. The individual lead level did not exceed the TSMD site-specific criterion ($T_{10} = 150 \text{ mg/kg}$).

Summary

LSFR 0.4 had a fully supporting MSCI score of 18, which was the highest among in LSFR stations. The community was similar to BIOREF stream communities in the number of sensitive taxa and taxa less tolerant of organic pollution/disturbance, as well as diversity and evenness. However, the DMT assemblage was not similar to those found in BIOREF streams, as was the case at all LSFR stations. Stream habitat was comparable to the SHAPP control; however, fine sediment was abundant, in this case appearing like bank soil. The adjacent land was subject to grazing, and there was little vegetated riparian corridor. Feral hogs were also abundant in the area (landowner pers. comm.), and their destructive foraging behavior likely contributed to the sediment load.

Water quality constituents did not exceed WQS (MoDNR 2018c) or obviously influence the macroinvertebrate community composition. Dissolved metals concentrations did not exceed WQS chronic toxicity thresholds (MoDNR 2018c) and were similar to or lower than immediately upstream. Fine sediment metals levels were well below PEC thresholds and close to the control stream levels. Sediment deposition was a factor that could negatively affect the community composition. However, biological metrics indicate the presence of a high quality macroinvertebrate community that does not appear to have been exposed to influences that affected upstream stations. As with the two upstream stations (LSFR 10.4 and LSFR 3.0), it is uncertain whether influences that are affecting upstream stations have not yet reached this point, or if substantial influences present in the past have since been removed. Either scenario is a problem for this location or points downstream, which may include the St. Francis River.

Overall LSFR – Areas of Interest

Observations of trends across all LSFR stations may identify areas of interest. The SHAPP identified moderate to heavy coverage of fine sediment throughout the study area. Heavy coverage was observed at eight of the 10 stations in LSFR; however, fine sediment at LSFR 21.1, LSFR 16.6, and LSFR 13.7 may have substantially influenced other habitat features as well. Several water quality constituents including nutrients, sulfate, and chloride were apparently added in low concentrations at LSFR 16.0, downstream of Saline Creek. These constituents were present in incrementally decreasing concentrations among the remaining downstream LSFR study sites to the end of the study area. Dissolved lead was present upstream at LSFR 21.2 and LSFR 21.1, but it was highest at LSFR 16.6 and LSFR 13.7. Dissolved nickel was added at LSFR 16.0 and decreased at all remaining downstream stations. Fine sediment metals were observed in potentially toxic levels from LSFR 21.2 downstream to LSFR 10.4 before decreasing. The number of metals and their concentrations were highest at LSFR 21.1, 16.6, 13.7, 13.2, and 13.0. A specific area of added interest includes the roughly 3 miles of mainstem LSFR between the upstream portion of the study area for this project and downstream of the

previous study (MDNR 2020) to identify a source and potential pulse of mine-related material. Other areas include Sweetwater Branch (LSFR 21.1), tributaries upstream of Fredericktown City Lake (LSFR 16.6), upstream of and including Spiva Branch and in the Old Highway 67 bridge pool (LSFR 13.7 and LSFR 13.2), and Mill Creek (LSFR 13.0). Biological assessments and/or fine sediment metal characterization studies should be conducted in the specific areas of interest to identify conditions and sources.

As noted in the summaries of the downstream three LSFR stations, it is unknown whether the metals-rich fine sediment pulse that has apparently influenced the support status of upstream stations has not yet made it to the downstream stations, or if the sediments have moved through the system. In either case, these three stations with fully supporting MSCI scores (LSFR 10.4, LSFR 3.0, and LSFR 0.4) are areas of interest as well. Metals-rich fine sediment in stream deposits should be addressed to prevent a pulse from moving into fully supporting areas of LSFR. Sediment and total metals should be monitored at these three downstream stations to track trends. Studies should be conducted to determine whether benthic sediment metals from LSFR are present in the St. Francis River.

3.1.2 Village Creek (VC) Stations

Aspects of the biological assessment and fine sediment characterization project were examined to identify the status or ability of each station to support the beneficial use, as well as the physical and chemical conditions among stations. A summary of results at each station may identify potential influences at that station. An overall look at potential influences may identify specific area of interest in each stream. VC stations are arranged from upstream to downstream.

Station VC 0.2 – Upstream of Shays Creek

Stream Habitat Assessment

The VC 0.2 stream habitat score was 79 percent of the SHAPP control score and was considered comparable (Table 6). Notable features included fewer velocity depth regimes, narrow channel flow status, less vegetative protection on both banks, and a narrow riparian corridor on both banks. Both banks were very stable.

Macroinvertebrate Stream Condition Index

Village Creek 0.2 had a partially supporting MSCI score of 14 in the fall (Table 8). Three of the four metric scores contributed to the suboptimal MSCI, with only TR attaining an optimal score of 5. These metrics suggest that, although the community has a similar number of taxa as BIOREF streams, the taxa tended to be less sensitive, more tolerant of organic pollution/disturbance, and the community was less diverse than reference communities.

Village Creek 0.2 was also partially supporting in spring, with an MSCI score of 14 (Table 9). Taxa richness was again the only metric to be within the optimal range. As was observed in fall, the community had a similar taxa richness as those found in BIOREF streams of the EDU, but with fewer sensitive taxa, taxa that were more tolerant of organic pollution/disturbance, and with less diversity.

Dominant Macroinvertebrate Taxa

The fall VC 0.2 DMT composition comparison with BIOREF streams is presented in Table 11. Five DMT were found in common with BIOREF streams, four of which were prevalent at both stations. *Hyalella azteca* was in common at this station but ranked low downstream. Five DMT were absent (2 taxa) or ranked low (3 taxa) at VC 0.2. *Caenis anceps* and *Maccaffertium mediopunctatum* were absent from both VC stations. The three remaining DMT ranked low at both stations in fall.

The spring VC 0.2 DMT composition comparison with BIOREF streams is presented in Table 12. Five DMT were in common with BIOREF streams, four of which were prevalent at both stations. *Hyalella azteca* was in common at this station and ranked low downstream. Five DMT were absent (1 taxon) or ranked low (4 taxa) at VC 0.2. *Caenis anceps* was the only DMT absent from this station.

Water Quality

Several water quality constituents were notable; however, none of the constituents exceeded WQS (MoDNR 2018c) at VC 0.2A and VC 0.2B (duplicates) in fall (Table 14). Specific conductance values (412.1 $\mu\text{S}/\text{cm}$ each) were highest among all Fredericktown area stations. Sulfate (27.1 and 28.3 mg/L, respectively) and chloride (6.43 and 5.29 mg/L, respectively) were present. Total nitrogen (0.53 mg/L each), nitrate+nitrite as N (0.30 and 0.31 mg/L, respectively), and total phosphorus (0.023 and 0.24 mg/L, respectively) exceeded EPA (2000) suggested guidelines. The ammonia-N concentration was below laboratory detection (<0.02 mg/L) in the VC 0.2A sample, but it was present (0.025 mg/L) in the duplicate VC 0.2B sample at an estimated concentration that was below practical laboratory quantitation limits.

Several water quality constituents were notable, but none exceeded WQS (MoDNR 2018c) in spring (Table 15). Specific conductance (252 $\mu\text{S}/\text{cm}$ each) was much lower than in fall, possibly due to a higher discharge (10.1 cfs). Sulfate (16.9 mg/L) and chloride (4.08 mg/L) were present. Turbidity (3.0 NTU), total nitrogen (0.78 mg/L), nitrate+nitrite as N (0.78 mg/L), and total phosphorus (0.023 mg/L) exceeded EPA (2000) suggested guidelines. The ammonia as N concentration was below laboratory detection (<0.02 mg/L) at VC 0.2 in spring.

Dissolved Metals

Dissolved metals were present in VC 0.2A and VC 0.2B duplicate samples in fall (Table 17). Arsenic (0.82 and 0.82 $\mu\text{g}/\text{L}$, respectively) was present in low concentrations in the duplicate samples. Barium (102.0 and 101.0 $\mu\text{g}/\text{L}$, respectively) was among the highest concentrations observed in Fredericktown area streams. Lead (0.57 and 0.56 $\mu\text{g}/\text{L}$, respectively) was present in low concentrations, and nickel (<0.50 $\mu\text{g}/\text{L}$) was below detectable concentrations. All other metals analyzed were either not detected or were found in low concentrations at VC 0.2 in fall. None of the dissolved metals exceeded WQS (MoDNR 2018c).

Spring VC 0.2 dissolved metals results are presented in Table 18. Arsenic ($<0.50 \mu\text{g/L}$) and lead ($<0.50 \mu\text{g/L}$) were not detected in the spring sample. Barium ($39.9 \mu\text{g/L}$) and nickel ($1.31 \mu\text{g/L}$) were observed in low concentrations. None of the dissolved metals exceeded WQSS (MoDNR 2018d).

Fine Sediment Metals

Several fine sediment total metals were notable at VC 0.2 (Table 20; Figures 6 and 10). Arsenic (63.0 mg/kg) exceeded the PEC threshold (33.0 mg/kg) by 1.9-times and was approximately 4-times higher than the Castor River control (Figure 6). Lead (125 mg/kg) nearly reached the PEC threshold (128 mg/kg) and was approximately 3-times higher than the control (Figure 10). The measures combining cadmium, lead, and zinc ($\sum \text{PEQ}_{\text{Cd, Pb, Zn}} = 1.22$) did not exceed the threshold ($T_{10} > 7.92$), and the mean $\text{PEQ}_{\text{metals}}$ (0.59) did not exceed the normalized threshold (mean $\text{PEQ}_{\text{metals}} \geq 1.11$) for all metals combined. The individual lead level did not exceed the TSMD site-specific criterion ($T_{10} = 150 \text{ mg/kg}$). Silver (0.268 mg/kg) was observed at a level that was much lower than the PEC (2.2 mg/kg) and only at this VC station.

Summary

VC 0.2 had partially supporting MSCI scores in fall and spring. The DMT comparison showed a different community composition than is expected to occur in BIOREF streams. Stream habitat was comparable to the SHAPP control and should not have been a substantial influence on the support status. Neither water quality analyses nor dissolved metals concentrations identified obvious effects to the macroinvertebrate community in either season.

The VC drainage includes eastern portions of the Mine LaMotte tailings, which may have contributed to fine sediment metals observed upstream of Shays Creek (Figures 2 and 3; Appendix B). Mine-related fine sediment metals were present in potentially toxic levels and may have contributed to the altered community in both seasons. Total arsenic was present at a potentially toxic level, and lead was near the PEC threshold in the upstream sample.

Station VC 1.7 – Downstream of Shays Creek

Stream Habitat Assessment

Stream habitat at VC 1.7 was comparable, having a 78 percent similarity with the SHAPP control (Table 6). Notable features included heavy sediment deposition, little vegetative protection on both banks, and a narrow riparian corridor on the right bank. The left bank was stable, but the right bank was moderately unstable.

Macroinvertebrate Stream Condition Index

Village Creek 1.7 had a fully supporting MSCI score of 16 in the fall (Table 8). Two of the four metrics contributed to the slightly lower, yet optimal MSCI score. The EPTT and BI metric values were outside the optimal range and attained metric scores of 3. The TR and SDI metric values were within the optimal range, and each scored 5. The macroinvertebrate community at VC 1.7 was made up of slightly fewer sensitive taxa that were more tolerant to organic pollution/disturbance relative to BIOREF stream communities. However, there were more taxa and slightly greater diversity than the upstream VC station.

Village Creek 1.7A and 1.7B (duplicates) had partially supporting MSCI scores of 14 in the spring (Table 9). Metric values and scores were similar between duplicate samples, with three metric values contributing to the suboptimal MSCI scores. Only the TR metric values exceeded the optimal scoring threshold. The community had a similar number of taxa as BIOREF streams, but it was less sensitive, more tolerant of organic influences or disturbance, and less diverse than would be expected to occur in the reference condition.

Dominant Macroinvertebrate Taxa

The VC 1.7 fall DMT composition as compared to BIOREF streams is presented in Table 11. Four taxa were found in common with BIOREF DMT, all of which were found upstream. Six DMT were absent (2 taxa) or ranked low (4 taxa). *Caenis anceps* and *Maccaffertium mediopunctatum* were absent at this station and the upstream station. *Hyaella azteca* ranked low at this station but was in common upstream. The three remaining taxa ranked low at both stations.

The VC 1.7A and 1.7B spring duplicate sample DMT composition compared to BIOREF streams is shown in Table 12. Four DMT at VC 1.7A and five DMT at VC 1.7B were found in common with BIOREF streams. Four of the DMT were prevalent in the duplicates and the upstream station. *Thienemannimyia* grp. was in common at one of the duplicates and ranked low at the other. Six DMT were absent (1 taxon) or ranked low (5 taxa) at VC 1.7A and five were absent (2 taxa) or reduced (3 taxa) at VC 1.7B. *Acentrella* spp. was absent from the duplicates and ranked low upstream. *Caenis anceps* was absent or ranked low in the duplicates and was absent upstream. *Hyaella azteca* ranked low in the duplicates, but it was again in common upstream as it was in fall. The two remaining taxa ranked low in the duplicates.

Water Quality

Several water quality constituents were notable at VC 1.7 in fall (Table 14), but none exceeded WQS (MoDNR 2018c). Specific conductance (404 μ S/cm) was slightly lower than the upstream VC duplicate readings. Sulfate (26.6 mg/L) was relatively similar to upstream, but chloride (7.82 mg/L) increased slightly. Turbidity (3.8 NTU), total nitrogen (0.88 mg/L), nitrate+nitrite as N (0.56 mg/L), and total phosphorus (0.054 mg/L) exceeded EPA (2000) guidelines, and all were present in higher concentrations than upstream. Ammonia as N (0.060 mg/L) was detected in a very low concentration, but it was higher than upstream.

No water quality constituents analyzed for the VC 1.7A and VC 1.7B duplicate samples in spring (Table 18) exceeded WQS (MoDNR 2018c). NFR concentrations (31.0 mg/L and 30.0 mg/L, respectively) were considerably higher in the VC 1.7 duplicates than VC 0.2 (<5 mg/L) upstream. Specific conductance (284 μ S/cm each) readings were also higher than upstream. Sulfate (22.1 and 23.2 mg/L) and chloride (4.66 and 4.15 mg/L) were present, with sulfate being higher than upstream. Turbidity (10.0 and 12.0 NTU), total nitrogen (1.08 and 0.96 mg/L), nitrate+nitrite as N (0.76 and 0.77 mg/L), and total phosphorus (0.060 and 0.51 mg/L) exceeded EPA (2000) guidelines. Each of these constituents, except nitrate+nitrite as N, was slightly higher in the downstream VC samples. The ammonia as N concentration was below laboratory detection (<0.02 mg/L) in VC 1.7 duplicate samples, as it was upstream.

Dissolved Metals

Several dissolved metals were present in the fall VC 1.7 sample (Table 17). Arsenic (1.23 µg/L) was present, and the barium (107.0 µg/L) concentration was highest among Fredericktown area streams. Lead (1.11 µg/L) and nickel (0.51 µg/L) were present in low concentrations; however, they were higher than the duplicate samples collected immediately upstream. None of the dissolved metals exceeded WQS (MoDNR 2018c) in fall.

Dissolved metals were notable in VC 1.7A and VC 1.7B spring duplicate samples (Table 18). Arsenic (<0.50 µg/L) was not detected at this station. Barium (41.9 and 42.9 µg/L) was observed in the duplicates (VC 1.7A and VC 1.7B, respectively). Lead (0.77 and 0.76 µg/L) and nickel (4.34 and 4.27 µg/L) were present in spring in higher concentrations than the upstream VC station. None of the dissolved metals exceeded WQS chronic toxicity thresholds (MoDNR 2018c).

Fine Sediment Metals

Several fine sediment total metals were remarkable at VC 1.7 (Table 20; Figure 6 and 10). Arsenic (37.5 mg/kg) exceeded the PEC threshold (33.0 mg/kg) by 1.14 times and was over twice as high as the Castor River control (Figure 6). Total lead (203.0 mg/kg) exceeded the PEC threshold (128 mg/kg) by 1.59 times, was substantially higher than upstream, and was approximately 4-times higher than the control (Figure 10). The combination of cadmium, lead, and zinc ($\sum \text{PEQ}_{\text{Cd, Pb, Zn}} = 1.76$) did not exceed the threshold ($T_{10} \geq 7.92$), and the mean $\text{PEQ}_{\text{metals}}$ (0.55 mg/kg) did not exceed the threshold (mean $\text{PEQ}_{\text{metals}} \geq 1.11$) for all metals combined. The individual lead level also exceeded the TSMD site-specific criterion ($T_{10} = 150$ mg/kg).

Summary

VC 1.7 had a fully supporting MSCI score in fall and a partially supporting score in spring. The DMT group was not similar to the top 10 BIOREF taxa in either season. Stream habitat was comparable to the SHAPP control; however, heavy sediment deposition was observed in VC. Water quality constituents did not exceed WQS (MoDNR 2018c); however, nutrient concentrations were consistently slightly higher downstream. Dissolved metals such as arsenic, nickel, and lead were found in low concentrations, yet they were consistently higher than the station immediately upstream. Total arsenic and lead in fine sediment exceeded the PEC thresholds. Heavy fine sediment, as well as fine sediment metals may have affected the VC 1.7 macroinvertebrate community. Sources for fine sediment and total metals to VC appear to be upstream of Shays Creek, as well as downstream. In an earlier study of Fredericktown area streams, Shays Creek was found to have heavy fine sediment deposition, and total arsenic and lead exceeded PECs (MoDNR 2020). Sources were suggested to be the Slime Pond and Mine LaMotte tailings (MoDNR 2020). The Slime Pond spill flows to Shays Creek, and the Mine LaMotte tailings pile to the east of the pond appears to include the VC watershed (Figures 2 and 3; Appendix B). Both sources may contribute tailings/chat to the metals-rich fine sediment found at both VC stations.

Overall VC – Areas of Interest

VC 0.2 had partially supporting MSCI scores for both seasons, but VC 1.7 (downstream of Shays Creek) scores were fully supporting in fall and partially supporting in spring. Stream habitat was comparable to the SHAPP control at both stations, but heavy sediment coverage was observed at VC 1.7. Water quality nutrient concentrations were slightly higher at VC 1.7 than immediately upstream, but all were observed in low concentrations. Dissolved metals (arsenic, lead, and nickel) were present in low or non-detectable concentrations at both stations. Arsenic and lead were observed at both stations in fall; lead and nickel were present at both stations in spring. For metals present in detectable concentrations, levels were greater at VC 1.7 downstream.

The total fine sediment arsenic concentration exceeded the PEC at both stations; however, it was nearly 2-fold higher at VC 0.2 upstream of Shays Creek than at VC 1.7, which is downstream of the confluence. Conversely, total lead was near the PEC at VC 0.2 and exceeded the toxicity threshold at VC 1.7. Specific areas of interest include upstream of VC 0.2 and downstream from VC 1.7. Biological assessments and/or fine sediment metal characterization studies should be conducted upstream of VC 0.2 to identify conditions and sources, as well as downstream of VC 1.7 to identify the extent of metals VC sediment.

3.1.3 Saline Creek (SC) Stations

Aspects of the biological assessment and fine sediment characterization project were examined to identify the ability of each station to support the beneficial use, as well as the physical and chemical conditions among stations. A summary of results at each station may identify potential influences at that station. An overall look at potential influences may identify specific areas of interest in each stream. SC stations are arranged from upstream to downstream.

Station SC 3.2 – Upstream of Goose Creek

Stream Habitat Assessment

The SC 3.2 stream habitat was comparable (82 percent similarity) to the SHAPP control, with the second highest SHAPP score among SC stations (Table 6). SHAPP features that reduced the score included a narrow channel, less vegetative protection on the left bank, and a narrow wooded riparian corridor on the left bank. Both banks were very stable.

Macroinvertebrate Stream Condition Index

SC 3.2 had a fully supporting MSCI score of 16 in the fall (Table 8). Two of the four metric values had suboptimal individual scores. The TR and SDI metrics each received optimal scores of 5, but the EPTT and BI metric values were slightly outside their optimal scoring ranges. These metrics indicated the community was similar in size and diversity to BIOREF streams, but it had fewer sensitive taxa and more taxa tolerant of organic pollution/disturbance.

SC 3.2 was fully supporting in spring with an MSCI score of 16 (Table 9). Two of the four individual metric values had suboptimal scores. The EPTT and SDI each received suboptimal metric scores of 3, and the TR and BI metric values reached the optimal range. The SC 3.2 macroinvertebrate community had a large number of taxa that tended to be intolerant of organic pollution/disturbance; however, it was also less sensitive and less diverse than BIOREF streams.

Dominant Macroinvertebrate Taxa

The DMT composition comparing the SC 3.2 fall sample with BIOREF streams is presented in Table 11. Six DMT were in common with BIOREF streams, which was the most observed among SC stations. Four taxa were absent (3 taxa) or reduced (1 taxon) at this station.

Tricorythodes spp., *Maccaffertium mediopunctatum*, and *Cricotopus/Orthocladius* grp. were absent, and Acarina ranked low.

The DMT composition comparing the SC 3.2 spring sample with BIOREF streams is presented in Table 12. Four DMT were in common with BIOREF streams at this station. Six taxa were absent (2 taxa) or ranked low (4 taxa). *Caenis anceps* and *Acentrella* spp. were the only DMT to be absent from this station, and they were absent or reduced at all SC stations. The four remaining reduced taxa were absent or reduced at most stations.

Water Quality

Several SC 3.2 water quality constituents were noteworthy in fall, but none exceeded WQS (MoDNR 2018c) (Table 14). NFR (8.0 mg/L), sulfate (11.2 mg/L), and chloride (8.48 mg/L) were present. Turbidity (13.0 NTU), total nitrogen (0.89 mg/L), nitrate+nitrite as N (0.41 mg/L), and total phosphorus (0.088 mg/L) exceeded EPA (2000) suggested guidelines. Ammonia as N (0.059 mg/L) was detected at this station.

Several water quality constituents were notable, but none exceeded WQS (MoDNR 2018c) at SC 3.2 in spring (Table 15). Specific conductance (420 μ S/cm) was higher at this station than downstream. Sulfate (10.4 mg/L) and chloride (6.21 mg/L) were present in low concentrations. Turbidity (4.1 NTU), total nitrogen (0.96 mg/L), nitrate+nitrite as N (1.06 mg/L), and total phosphorus (0.022 mg/L) exceeded EPA (2000) guidelines. Total nitrogen and nitrate+nitrite as N were slightly higher at this upstream station than other SC stations in spring. Ammonia as N (<0.02 mg/L) was below laboratory detection in the spring sample.

Dissolved Metals

Several metals were notable at SC 3.2 in fall (Table 17). Arsenic (0.84 μ g/L) was present in a low concentration, but it was slightly higher than all other SC stations in fall. Lead (<0.50 μ g/L) was not detected at this station, and the nickel concentration was below laboratory detection (<0.50 μ g/L). All metals included in the analyses were well below WQS chronic toxicity thresholds (MoDNR 2018c).

Spring dissolved metals concentrations for SC 3.2 are presented in Table 18. Dissolved arsenic and lead were below detectable concentrations (<0.50 μ g/L each) at this and all SC stations in spring. Nickel (0.82 μ g/L) was present at SC 3.2 only in spring at a low concentration. All dissolved metals concentrations were below WQS chronic toxicity thresholds (MoDNR 2018c).

Fine Sediment Metals

Fine sediment metals were present in SC 3.2 samples, but all were below potential toxicity thresholds (Table 20). Arsenic (22.3 mg/kg) was below the PEC threshold (33.0 mg/kg), but it was the highest level among SC stations and slightly higher than the Castor River control. Lead

(30.8 mg/kg) was approximately one-third of the PEC (128 mg/kg), lowest among all stations in this study, and slightly lower than the control.

Summary

SC 3.2 had fully supporting MSCI scores in fall and spring. The DMT comparison in fall indicated the community was relatively similar to BIOREF streams in fall and much different in spring. The stream habitat score was comparable to the control site and should be capable of supporting a similar community. Water quality constituents were not an obvious influence on the community composition in either season. Dissolved arsenic was present only in the fall at a very low concentration, similar to other SC stations. Lead was not detected in either season, and nickel was only detected in spring at a very low concentration. Total fine sediment metals did not exceed PECs, and levels were similar to the control. SC 3.2 had a relatively high quality macroinvertebrate community with no obvious stressors.

Station SC 2.0 – Downstream of Goose Creek

Stream Habitat Assessment

The SC 2.0 stream habitat score was 86 percent of the SHAPP control, the highest of the four SC sites, and was considered comparable (Table 6). Notable features, however, included heavy sediment deposition, marginal riffle quality, and a narrow riparian corridor on the left bank. Sediment deposition at this site was among the highest, and riffle quality was the lowest observed in SC. Banks were very stable.

Macroinvertebrate Stream Condition Index

SC 2.0 had a fully supporting MSCI score of 16 in fall (Table 8). Two metric values (EPTT and BI) had suboptimal individual scores of 3, and the TR and SDI metrics attained metric scores of 5. This shows the fall community had fewer sensitive taxa and was more tolerant of organic pollution/disturbance than BIOREF communities. Compared to the station immediately upstream, SC 2.0 had slightly fewer taxa and less diversity/evenness in fall.

Saline Creek 2.0 also had a fully supporting MSCI score of 16 in the spring (Table 9). Similar to fall, EPTT and BI had suboptimal individual scores of 3, and the TR and SDI metrics attained metric scores of 5. The spring community had slightly fewer sensitive taxa and more taxa tolerant of organic pollution/disturbance than BIOREF communities. The community was larger, more sensitive, and more diverse than upstream; however, it was also more tolerant of organic pollution/disturbance.

Dominant Macroinvertebrate Taxa

The SC 2.0 fall 2018 DMT composition is presented in Table 11. Five DMT were in common with the BIOREF streams and were also prevalent upstream. The five remaining taxa were absent (1 taxon) or ranked low (4 taxa), four of which were absent or ranked low at the upstream station. *Maccaffertium mediopunctatum* was the only taxon that was absent, as it was upstream. Although *Isonychia bicolor* was among the DMT at SC 3.2 upstream, it ranked low at SC 2.0. Otherwise, taxa that were absent or reduced were similarly rare at the station upstream.

The SC 2.0 spring DMT composition is shown in Table 12. Four DMT were in common with BIOREF streams and were abundant upstream as well. Six taxa were absent (1 taxon) or ranked low (5 taxa). *Caenis anceps* was absent at this station as well as upstream. All six taxa that were absent or ranked low at SC 2.0 were ranked low at the upstream station as well.

Water Quality

Several water quality constituents were notable or exceeded EPA (2000) suggested guidelines at SC 2.0 in fall (Table 14); however, none exceeded WQS (MoDNR 2018c). NFR (6.0 mg/L), sulfate (11.7 mg/L), and chloride (7.22 mg/L) were present, although chloride dropped slightly from the station upstream. Turbidity (8.2 NTU), total nitrogen (0.69 mg/L), nitrate+nitrite as N (0.38 mg/L), and total phosphorus (0.067 mg/L) exceeded EPA (2000) guidelines, but these values all were lower than upstream. The ammonia-N (0.020 mg/L) concentration was below laboratory practical quantitation limits and was lowest among SC stations.

Several water quality constituents were notable or exceeded EPA (2000) suggested guidelines at SC 2.0 in spring (Table 15); however, none of the constituents exceeded WQS (MoDNR 2018c). NFR (5.00 mg/L) was present, and sulfate (9.72 mg/L) and chloride (5.33 mg/L) dropped slightly from the station upstream. Turbidity (4.3 NTU), total nitrogen (0.64 mg/L), nitrate+nitrite as N (0.68 mg/L), and total phosphorus (0.026 mg/L) exceeded EPA (2000) guidelines, but total nitrogen and nitrate+nitrite as N were lower than upstream. Ammonia-N (<0.02 mg/L) was below detectable concentrations.

Dissolved Metals

Several metals were notable at SC 2.0 in fall (Table 17). Arsenic (0.80 µg/L) was present in a slightly lower concentration than upstream. Lead (<0.50 µg/L) again was not detected. Although nickel was below detectable concentrations upstream at SC 3.2, it was observed in a low concentration (1.02 µg/L) downstream of Goose Creek at SC 2.0. None of the dissolved metals exceeded WQS chronic toxicity thresholds (MoDNR 2018c).

Several dissolved metals were also notable at SC 2.0 in spring (Table 18). Arsenic (<0.50 µg/L) and lead (<0.50 µg/L) were not detected, but nickel (1.89 µg/L) was present in a low concentration that was slightly higher than upstream. None of the dissolved metals exceeded WQS chronic toxicity thresholds in spring (MoDNR 2018c).

Fine Sediment Metals

Fine sediment metals were notable at SC 2.0 (Table 20). Arsenic (15.7 mg/kg) was about half of the PEC threshold (33.0 mg/kg), lower than the station upstream, and similar to the Castor River control. Lead (34.5 mg/kg) was well below the PEC threshold, slightly higher than upstream, and similar to the control. Nickel (80.9 mg/kg) exceeded the PEC threshold (48.6 mg/kg) by 1.66-fold, was approximately 5-times higher than the upstream station and the control. Cadmium, lead, and zinc combined ($\sum \text{PEQ}_{\text{Cd, Pb, Zn}} = 0.41$) did not exceed the threshold ($T_{10} \geq 7.92$), and the mean $\text{PEQ}_{\text{metals}}$ (0.037) did not exceed the threshold (mean $\text{PEQ}_{\text{metals}} \geq 1.11$) for all metals combined.

Summary

Although SC 2.0 attained fully supporting MSCI scores in both sampling seasons, there were fewer sensitive and more tolerant taxa than in BIOREF streams. The DMT comparison also identified the community as different from the reference condition. Stream habitat was comparable to the SHAPP control, but with heavy sediment coverage as part of the substrate. Water quality constituent concentrations were similar or lower than upstream, and all were below WQS (MoDNR 2018c). Dissolved arsenic and nickel were intermittently present in low concentrations, but lead was not detected in the samples. Benthic fine sediment total nickel exceeded the PEC threshold for the first time in SC. The heavy coverage and the presence of metals in fine sediment may have affected the community composition somewhat; however, these factors did not prevent fully supporting MSCI scores. Goose Creek drains the eastern portion of the Anschutz-Madison Mine (OU2) area, which may have contributed fine sediment and metals to SC (Figures 2 and 3; Appendix B).

Station SC 1.3 – Downstream of Unnamed Tributary

Stream Habitat Assessment

The Saline Creek 1.3 stream habitat assessment score was 81 percent of the SHAPP control, which is considered comparable to reference conditions (Table 6). Suboptimal features included fewer velocity depth regimes, less vegetative protection on both banks, and a narrow riparian corridor on the right bank. Despite the riparian corridor and vegetative protection issues, banks were very stable.

Macroinvertebrate Stream Condition Index

SC 1.3 had a partially supporting MSCI score of 10 in fall (Table 8). Three metric values (TR, BI, and SDI) attained suboptimal scores of 3, and one metric (EPTT) received a score of 1. The macroinvertebrate community was substantially smaller, less sensitive, more tolerant of organic pollution/disturbance, and less diverse than BIOREF communities. Furthermore, three of the metric values dramatically changed from the station immediately upstream. The TR metric value decreased by 30 taxa (40 percent RPD) and the EPTT dropped by 13 taxa (96 percent RPD) from the station immediately upstream. The BI metric value was only 0.3 units higher, but the SDI decreased by 19 percent (RPD).

SC 1.3 had a partially supporting MSCI score of 14 in spring (Table 9). Only TR attained an optimal individual metric score. Biological metrics indicate that the macroinvertebrate community was similar in size to BIOREF stream communities but substantially less sensitive, more tolerant to organic pollution/disturbance, and less diverse and evenly distributed. Although the TR metric score was in the optimal range, the number of taxa decreased by 22 (nearly 20 percent RPD). The EPTT metric value dropped by 6 taxa (24 percent RPD), and there was substantially less diversity than the station immediately upstream. There was no change in BI values between the two stations.

Dominant Macroinvertebrate Taxa

The prevalence of DMT at SC 1.3 was compared among BIOREF stations in fall (Table 11). Three DMT were in common with BIOREF streams, which was much fewer DMT than upstream. Two chironomid taxa (*Tanytarsus* spp. and *Cricotopus/Orthocladius* grp.) and the water mite (Acarina) were prevalent at this station. Seven taxa were absent (5 taxa) or reduced (2 taxa) at this station. Two taxa (*Tricorythodes* spp. and *Maccaffertium mediopunctatum*) were absent or ranked low at all SC stations. *Caenis anceps* and *Hyaella azteca* were absent for the first time in SC. *Isonychia bicolor* was absent from SC 1.3 and reduced immediately upstream. Two taxa (*Stenelmis* spp. and *Caenis latipennis*) were reduced for the first time in SC.

The spring SC 1.3 DMT composition is shown in Table 12. Four DMT were found in common with BIOREF streams, three of which were also in common at the stations upstream. *Caenis latipennis* remained in common with BIOREF streams, along with *Cricotopus/Orthocladius* grp. *Tanytarsus* spp., and *Thienemannimyia* grp. (Chironomidae), which increased in abundance from upstream. Six DMT were absent (1 taxon) or ranked low (5 taxa) at SC 1.3; five were absent or reduced at all SC stations. *Caenis anceps* was absent from this station. *Stenelmis* spp. decreased in abundance and ranked low at this station, yet it was prevalent at both upstream stations.

Water Quality

Several water quality constituents were notable at SC 1.3 in fall; however, none exceeded WQS (MoDNR 2018c; Table 14). Specific conductance (374.7 μ S/cm) was highest among SC stations, and NFR (6.0 mg/L) and chloride (7.37 mg/L) were present. Sulfate (29.5 mg/L) was nearly 3-fold higher than the stations upstream. Turbidity (10.0 NTU), total nitrogen (0.91 mg/L), nitrate+nitrite as N (0.57 mg/L), and total phosphorus (0.096 mg/L) exceeded EPA (2000) guidelines; all but turbidity were the highest concentrations observed in SC. Ammonia as N (0.068 mg/L) was also detected in the highest concentration among stations but well below the chronic WQS concentration. Sulfate and nutrients were highest among SC stations, and the sulfate concentration was over 2-times higher than immediately upstream.

Water quality constituents in the spring sample are presented in Table 15. None of the constituents exceeded WQS (MoDNR 2018c). NFR (<5.0 mg/L) and chloride (5.52 mg/L) were present in concentrations similar to upstream stations. Sulfate (42.8 mg/L) was over 4-fold higher than either station upstream. Turbidity (3.7 NTU), total nitrogen (0.91 mg/L), nitrate+nitrite as N (0.57 mg/L), and total phosphorus (0.096 mg/L) exceeded EPA (2000) guidelines; all but turbidity were the highest concentrations observed in SC. Ammonia as N (0.068 mg/L) was also detected in the highest concentration among stations, but it was again well below the chronic WQS concentration.

Dissolved Metals

Several dissolved metals were notable at SC 1.3 in fall (Table 17). Dissolved arsenic (0.73 μ g/L) was detected at a slightly lower concentration than upstream stations. Cobalt, which was below laboratory detection levels in the upstream SC stations, was present in the highest concentration in SC 1.3 (19.7 μ g/L). As was the case at upstream stations, lead was not detected (<0.50 μ g/L) at SC 1.3. Nickel (48.1 μ g/L) increased to over half of the WQS (MoDNR 2018c) chronic

toxicity concentration (92.29 µg/L; hardness = 197 mg/L as CaCO₃) and was over 47-times higher than upstream.

Dissolved metals were identified in the spring SC 1.3 sample (Table 18). Arsenic (<0.50 µg/L) and lead (<0.50 µg/L) were not detected. Cobalt (51.9 µg/L) increased substantially from upstream and was in the highest concentration among SC sites. Nickel (85.8 µg/L) exceeded the WQS (MoDNR 2018c) chronic toxicity threshold (79.03 µg/L; hardness = 164 as CaCO₃), and increased by over 45-times from the station immediately upstream.

The WPP collected water samples from Unnamed Tributary between 1996 and 2019 that showed a range of dissolved metals, some of which may have been toxic to the aquatic community (MoDNR, WPP unpublished May 2019). Samples detected sulfate and several dissolved metals including cobalt, copper, and nickel. Cobalt ranged from 12.7 to 2060 µg/L (mean = 1376.8 µg/L, s.d. = 548.3) with only two readings below 130 µg/L. Copper ranged from 4.77 to 26.0 µg/L, (mean = 10.8 µg/L, s.d. = 5.4). In May 2019, copper (44.7 µg/L) exceeded the WQS (MoDNR 2018c) chronic toxicity threshold (36.58 µg/L; hardness = 519 mg/L as CaCO₃). Twenty-five nickel readings between 1996 and 2018 ranged from 190 to 2980 µg/L (mean = 2168.5 µg/L, s.d. = 719.5), with only three readings at or below 194 µg/L. Nickel (1210 µg/L; hardness = 519 mg/L as CaCO₃) observed in May 2019 exceeded the 2018 WQS. In fact, all of the 17 nickel values with recorded hardness values exceed chronic WQS (MoDNR 2018c). Sulfate concentrations ranged from 408 to 994 mg/L, (mean = 784.4 mg/L, s.d. = 150.6). Hardness as CaCO₃ values ranged from 943 to 1150 mg/L, (mean = 1042.6 mg/L, s.d. = 65.3), with a relatively low standard deviation in Unnamed Tributary between 1996 and 2018. Hardness values were approximately 4-times higher at SC 1.3 than Tollar Branch during the same period.

Fine Sediment Metals

Several fine sediment metals levels were remarkable at SC 1.3 (Table 20; Figures 6, 8, 10, and 12). Arsenic (12.1 mg/kg) was below the PEC (33.0 mg/kg) and was slightly lower than SC stations upstream and the Castor River control (Figure 6). Cobalt (267.0 mg/kg) increased by over 3-fold from upstream and was 40-times higher than the control (there is no PEC for cobalt). Copper (105.0 mg/kg) was near the PEC (149.0 mg/kg); it was approximately 10-fold higher than the nearest upstream station and 13-times higher than the control (Figure 8). Lead (156.0 mg/kg) exceeded the PEC threshold (128.0 mg/kg) by 1.22 times and was over 4-times higher than the station immediately upstream and the control (Figure 10). Nickel (216.0 mg/kg) exceeded the PEC threshold (48.6 mg/kg) by 4.44 times, was nearly 3-times higher than upstream, and was approximately 5-times higher than the control (Figure 12). The combination of cadmium, lead, and zinc ($\sum \text{PEQ}_{\text{Cd, Pb, Zn}} = 1.43$) did not exceed the threshold ($T_{10} \geq 7.92$), and the mean $\text{PEQ}_{\text{metals}}$ (0.99) also did not exceed the threshold (mean $\text{PEQ}_{\text{metals}} \geq 1.11$) for all metals combined; however, it was very close to the threshold. The individual lead level also exceeded the TSMD site-specific criterion ($T_{10} = 150$ mg/kg).

Summary

SC 1.3 had partially supporting MSCI scores in both fall and spring, with dramatic decreases in the taxa richness, EPT taxa, and diversity compared to upstream stations. Interestingly, the BI metric value did not change substantially from the station immediately upstream, suggesting organic pollution/disturbance was not a substantial contributor to the changes in biological metrics. The DMT comparison also indicated that the SC 1.3 community was much less like BIOREF streams, and different than upstream stations. Stream habitat was comparable to the SHAPP control and should not have substantially influenced the community composition. Water quality constituents were well below WQS thresholds and were similar to upstream. Sulfate, however, was 3 to 4-times higher than immediately upstream. Sulfate is a compound that can be associated with heavy metals mining (Brumbaugh et al. 2007; Allert et al. 2008; Schaidler et al. 2014). Dissolved cobalt was below detectable concentrations at upstream SC stations, but it was present during both seasons at SC 1.3. Nickel was also present in both seasons and exceeded the WQS (MoDNR 2018c) in spring. Total fine sediment lead and nickel exceeded PEC thresholds and were much higher than upstream. Total cobalt and copper increased substantially from upstream stations. Dissolved nickel, along with fine sediment total lead and nickel, were observed at levels above which toxic effects may be observed in the aquatic community, thus affecting the beneficial use designation. Unnamed Tributary drains a large tailings pond located in Cobalt Village (Figures 2 and 3; Appendix B – Saline Creek) and enters SC upstream of SC 1.3. It is a likely contributor of the dissolved and fine sediment metals.

Station SC 1.2 – Downstream of Tollar Branch

Stream Habitat Assessment

Stream habitat at SC 1.2 was not comparable (65 percent similarity) to the SHAPP control (Table 6). Notable features included heavy sediment deposition, narrow channel flow status, poor riffle quality, little vegetative protection on the left bank, and a narrow riparian corridor on both banks. Banks were very stable.

Macroinvertebrate Stream Condition Index

SC 1.2 had a partially supporting MSCI score of 10 in fall (Table 8). All metric values contributed to the very low MSCI score, with one in the non-supporting range. The EPTT metric attained the lowest possible score of 1, and TR, BI, and SDI each had scores of 3. These metrics were indicative of a much smaller, less sensitive, more tolerant of organic pollution/disturbance, and less diverse community than BIOREF streams. Additionally, the EPTT and BI metric values were farther from their optimal criteria thresholds than the remaining SC fall samples. These metrics identified a much less sensitive group that was more tolerant of organic pollution/disturbance than all SC stations.

Saline Creek 1.2 was partially supporting with an MSCI score of 12 in the spring (Table 9). All metric values attained suboptimal scores of 3, which suggests a much smaller community that was less sensitive, more tolerant to organic pollution/disturbance, and less diverse than BIOREF communities. The number of taxa decreased by 8 (12 percent RPD) from the station immediately upstream, and by 30 taxa (28 percent RPD) compared to SC 2.0. Remaining individual metrics were similar to those at the station immediately upstream.

Dominant Macroinvertebrate Taxa

The fall SC 1.2 DMT composition is presented in Table 11. One DMT (*Tanytarsus* spp.) was in common with the BIOREF streams at this station, as it was at all SC stations. Nine taxa were absent (6 taxa) or reduced (3 taxa) at this station. Five of those were absent or reduced at the majority of stations. Four taxa that were absent or reduced were among the DMT at the two most upstream stations. Among those included *Stenelmis* spp., *Caenis latipennis*, *Caenis anceps*, and *Hyalella azteca*.

The spring SC 1.2 DMT composition is shown in Table 12. Three DMT were in common with BIOREF streams. *Cricotopus/Orthocladius* grp., *Tanytarsus* spp., and *Thienemannimyia* grp. (Chironomidae) were the DMT at this station and the station immediately upstream. Seven taxa were absent (3 taxa) or ranked low (4 taxa), five of which were absent or ranked low at all SC stations. *Caenis latipennis*, which was prevalent at all upstream stations, ranked low for the first time in SC. *Stenelmis* spp. was reduced at this station and the station immediately upstream, but it was prevalent at the two upstream stations.

Water Quality

Several water quality constituents were notable, yet none exceeded WQS (MoDNR 2018c) at SC 1.2 in fall (Table 14). Discharge (20.8 cfs) increased from upstream. Specific conductance (353.7 μ S/cm) was slightly lower than immediately upstream, and NFR (7.0 mg/L) and chloride (6.92 mg/L) were present. The sulfate (25.9 mg/L) concentration was slightly lower than the station immediately upstream. Turbidity (11.0 NTU) increased slightly, while total nitrogen (0.79 mg/L), nitrate+nitrite as N (0.48 mg/L), and total phosphorus (0.082 mg/L) were lower than upstream; however, all exceeded EPA (2000) guidelines. Ammonia as N (0.052 mg/L) was detected in a slightly lower concentration than the station upstream.

Water quality constituents analyzed in spring did not exceed WQS (MoDNR 2018c) at SC 1.2 (Table 15). Discharge (24.1 cfs) nearly doubled from immediately upstream. NFR (7.0 mg/L) and chloride (6.82 mg/L) were present and increased relative to upstream stations. Sulfate (43.0 mg/L) was similar to the station immediately upstream. Turbidity (6.8 NTU), total nitrogen (0.89 mg/L), nitrate+nitrite as N (0.82 mg/L), and total phosphorus (0.029 mg/L) exceeded EPA (2000) guidelines and were slightly higher than upstream. Ammonia as N (0.013 mg/L) was also detected in a similar or slightly lower concentration than the station upstream.

Dissolved Metals

Several dissolved metals were notable at SC 1.2 in fall (Table 17). Arsenic (0.65 μ g/L) was observed in the lowest concentration among stations in fall. The cobalt concentration (13.9 μ g/L) was slightly lower than immediately upstream; however, it was the second highest level among Fredericktown area streams. SC 1.2 was the only SC station to have a detectable lead concentration (0.62 μ g/L), but at a level below practical laboratory quantitation. Nickel (41.1 μ g/L) decreased slightly from upstream, but it was still approximately half of the WQS chronic toxicity threshold of 85.51 μ g/L at hardness=180 mg/L as CaCO₃ (MoDNR 2018c). All dissolved metals analyzed were below WQS in fall.

Several dissolved metals were present at SC 1.2 in spring (Table 18). Arsenic ($<0.50 \mu\text{g/L}$) was not observed in spring. Cobalt ($49.3 \mu\text{g/L}$) was much higher in spring, again being found in a concentration second only to the station immediately upstream. As with each of the upstream SC stations, lead ($<0.50 \mu\text{g/L}$) was not observed at SC 1.2. Nickel ($82.3 \mu\text{g/L}$) exceeded the WQS (MoDNR 2018c) chronic toxicity threshold ($78.63 \mu\text{g/L}$ at hardness= 163 mg/L as CaCO_3). Metals concentrations observed at SC 1.2 were slightly lower than the station immediately upstream.

MoDNR's WPP sampled Tollar Branch numerous times between 1979 and 2016 for dissolved metals (WPP unpublished data). Several metals concentrations were notable, but WQS exceedances could not be determined due to the absence of hardness values. However, there were concentrations that may have exceeded standards under certain hardness conditions. Two samples in 1979 contained dissolved lead ($7.6 \mu\text{g/L}$ and $8.0 \mu\text{g/L}$) that would have been nearly twice the present day WQS at a hardness of 163 mg/L (as CaCO_3), which was the hardness value found in SC downstream of Tollar Branch. Nickel was present in samples collected on November 21, 1979 ($44.0 \mu\text{g/L}$) and again on August 9, 2002 ($11.7 \mu\text{g/L}$), one of which was similar to the nickel concentration ($41.1 \mu\text{g/L}$) at SC 1.2 in fall 2018. Neither nickel concentration would have exceeded WQS ($85.51 \mu\text{g/L}$) at the hardness observed (180 mg/L as CaCO_3) in fall at SC 1.2. However, recent observations demonstrate that Tollar Branch may still discharge dissolved nickel at concentrations similar to over 40 years ago. Historical fluctuations suggest Tollar Branch has the potential to contribute dissolved metals to SC.

Fine Sediment Metals

Several fine sediment metals were notable at SC 1.2 (Table 20; Figures 6, 8, 10, and 12). Although the SC 1.2 arsenic concentration (17.1 mg/kg) was slightly higher than immediately upstream and the Castor River control, it did not exceed the PEC (33.0 mg/kg) (Figure 6). Cobalt (317.0 mg/kg) increased by 50 mg/kg compared to immediately upstream and was 48-times that of the control. Copper (156.0 mg/kg) exceeded the PEC (149.0 mg/kg) by 1.05 times, increased by one-third from upstream, and was nearly 20-times higher than the control (Figure 8). Lead (315.0 mg/kg) exceeded the PEC threshold (128.0 mg/kg) by 2.46-times, doubled from the station immediately upstream, and was over 8-times higher than the control (Figure 10). Nickel (306.0 mg/kg) exceeded the PEC threshold (48.6 mg/kg) by 6.30-times, was 50 mg/kg higher than immediately upstream and nearly 20-times higher than the control (Figure 12). Silver (0.419 mg/kg) was present for the first time in SC at approximately 20 percent of the PEC threshold (2.2 mg/kg). Zinc (130.0 mg/kg) was approximately 28 percent of the PEC threshold, nearly double that of upstream, and nearly 2.5-times higher than the control. The mixture of cadmium, lead, and zinc ($\sum \text{PEQ}_{\text{Cd, Pb, Zn}} = 2.96$) did not exceed the threshold ($T_{10} \geq 7.92$); however, the mean $\text{PEQ}_{\text{metals}}$ threshold (1.57) was exceeded (mean $\text{PEQ}_{\text{metals}} \geq 1.11$) for all metals combined. The individual lead concentration also exceeded the TSMD site-specific criterion ($T_{10} = 150 \text{ mg/kg}$) by 2-fold.

Summary

SC 1.2 had a partially supporting MSCI score during both sample seasons with a much smaller, less sensitive and diverse community than BIOREF streams. The DMT assemblage was different than the BIOREF DMT, with consistently fewer DMT than all other stations in both seasons. This suggested there may be an additional influence affecting the community composition at this point in SC. Stream habitat was not comparable to the SHAPP control, which suggests habitat quality may have influenced the community and support status. SHAPP features such as sediment deposition likely affected riffle quality and possibly the channel flow status. Fine sediment may have been deposited by upstream influences or Tollar Branch; however, sediment was not likely due to bank sloughing, as banks were stable throughout the study area.

Water quality constituents were not obvious influences on the macroinvertebrate community during either season. Dissolved lead was observed for the first and only time in fall at a low concentration. Dissolved cobalt and nickel were present in slightly lower concentrations during both seasons than upstream, but nickel remained above the chronic toxicity WQS threshold in spring. Cobalt and nickel appear to have been contributed to SC 1.2 from upstream of SC 1.3, likely from Unnamed Tributary, as concentrations were consistently lower at the downstream SC station.

All SC 1.2 fine sediment metals (except arsenic) were found in higher concentrations than any SC station upstream. Total copper, lead, and nickel exceeded PEC thresholds, above which toxic effects are likely to be observed in the aquatic community. Fine sediment and total metals were prevalent and possibly added or accumulated from upstream sources or through discharge from Tollar Branch. Tollar Branch drains a large tailings pond located in Cobalt Village (Figures 2 and 3; Appendix B – Saline Creek).

Overall SC – Areas of Interest

Examination of aspects across all stations identified areas of interest for future study. The macroinvertebrate community was substantially altered from the BIOREF condition at SC 1.3 and SC 1.2 during both seasons. The SHAPP identified heavy deposits of fine sediment at SC 2.0 and at SC 1.2 that did not appear to be due to bank sloughing. Water quality constituents were relatively consistent from upstream to downstream. Low levels of dissolved metals such as cobalt and nickel were present at SC 2.0. Cobalt and nickel increased substantially at SC 1.3, with nickel exceeding the WQS (MoDNR 2018c) in spring. Nickel in fine sediments decreased at SC 1.2 in both seasons but remained above its PEC in spring. Cobalt and nickel that appear to have been contributed at SC 1.3 were observed downstream at LSFR 16.0. Additionally, the nickel contributed from SC was observed at all downstream LSFR stations, extending to LSFR 0.4 near the confluence with St. Francis River.

Fine sediment lead was potentially toxic at SC 2.0. Cobalt, copper, lead, and nickel were added at SC 1.3, with lead and nickel being present in potentially toxic levels. Fine sediment cobalt, copper, lead, nickel, silver, and zinc were prevalent at SC 1.2, with copper joining lead and nickel in exceeding potentially toxic threshold levels. Specific added areas of interest include Goose Creek (SC 2.0), Unnamed Tributary (SC 1.3), Tollar Branch (SC 1.2), as well as other

tributaries of SC within the study area and instream below the study area. Biological assessments and/or fine sediment metal characterization studies should be conducted on these tributaries to identify conditions, sources, and extent of effects in SC.

3.2 Overview – LSFR, Village Creek, and Saline Creek

Macroinvertebrate communities in LSFR appear to have been substantially affected by mine-related influences. An 8-mile reach from the most upstream station (LSFR 21.2) to downstream of Mill Creek (LSFR 13.0) were partially supporting of the warm water habitat beneficial use. Dissolved metals were added at various points in that reach, and the coverage of fine sediment was a potential influence at all stations. Most fine sediment within that affected reach appeared to be of uniform size and color resembling mine tailings/chat. Additionally, fine sediment total metals exceeded at least one toxicity threshold at all stations within the 8-mile reach. LSFR 10.4 was downstream of this 8-mile reach, and although fine sediment metals exceeded toxicity thresholds, this station attained a fully supporting MSCI score. For the 11-mile reach that extends from LSFR 21.2 to 10.4, each site had fine sediment metals that exceeded toxicity thresholds. Sampling locations in this reach bracketed the two tributaries (VC and SC) included in this study.

Two major tributaries of LSFR were included in this project, not only to determine their status and potential influences, but also to determine if they contributed to the status of LSFR stations. Both VC and SC had stations that were partially supporting of the warm water habitat protection designated use, likely due to mine-related influences. Both VC study stations had partially supporting MSCI scores in spring, but VC 1.7, downstream of Shays Creek, was fully supporting in fall. Influences included total arsenic above the PEC threshold at both stations, and excessive fine sediment with total arsenic and lead above the PECs downstream of Shays Creek. Neither fine sediment nor total metals appear to have been contributed to LSFR in the time surrounding this study.

Three of the four SC stations had mine-related contributions, and the two downstream stations had partially supporting MSCI scores in both seasons. Total lead associated with heavy fine sediment coverage was above the PEC in SC downstream of Goose Creek; however, the station attained fully supporting MSCI scores in both seasons. By comparison, SC had much lower partially supporting MSCI scores downstream of Unnamed Tributary and downstream of Tollar Branch. Important influences were potentially added to SC by Unnamed Tributary, which included dissolved nickel concentrations above the WQS chronic toxicity threshold (MoDNR 2018c), as well as total lead and nickel in fine sediment above PEC thresholds. Influences observed at SC 1.2 downstream of Tollar Branch included heavy sediment coverage; dissolved nickel above chronic toxicity thresholds; and total copper, lead, and nickel above PECs in the fine sediment. Fine sediment from SC may have reached LSFR, given that sediment was more abundant downstream from the confluence; however, none of the three total metals (copper, nickel, or lead) were obviously added to LSFR. Dissolved nickel, however, was apparently added to LSFR from SC, which in turn originated from Unnamed Tributary. Although dissolved nickel was below detectable concentrations upstream of SC, it was present in each LSFR sample from the SC/LSFR confluence to the station immediately upstream from the St.

Francis River. Nonetheless, VC and SC did not obviously contribute influences that affected LSFR stations during the timing of this study; however, both tributaries contain potentially toxic constituents that could enter LSFR.

3.3 Quality Assurance/Quality Control

Several duplicate samples were collected in Fredericktown area streams during the 2018-2019 study period and compared for similarity. For duplicate macroinvertebrate samples collected at VC 1.7 in the spring, the Quantitative Similarity Index (QSI) was used as a measure of quality control. The SMSBPP states that duplicate samples should have a QSI of at least 70 percent (MoDNR 2019a). Duplicate macroinvertebrate samples collected at VC 1.7 in the spring had a QSI of 82.4 percent.

Of the water quality constituents compared between VC 0.2A and VC 0.2B (WQ duplicate) in fall, only ammonia as N exceeded the 20 percent RPD threshold. This exceedance was likely due to very low concentrations in both samples. Ammonia as N was below detectable concentrations for the main sample, and the duplicate was an estimated value below the PQL. In spring 2019, duplicate water quality samples were collected at VC 1.7. All water quality constituents were within the acceptable 20 percent similarity range for VC 1.7A and VC 1.7B.

Duplicate fine sediment metals samples were collected at LSFR 21.2 and LSFR 16.3. A number of total metals were outside the acceptable 20 percent RPD limit defined in the QAPP. The differences may have been due to composite sampling of fine sediment metals that were unequally distributed in the substrate and further subsampling of the material during laboratory analysis. Differences between duplicate samples may be due to an unequal distribution of heavy metals in the fine sediment present in benthic substrate.

Table 5
 Stream Habitat Assessment Project Procedure (SHAPP) Features and Scores for LSFR Stations -
 Comparisons with the SHAPP Control Stream and Among Stations

Habitat Assessment Feature	21.2	21.1	16.6	16.3	16.0	13.7	13.0	10.4	3.0	0.4	SHAPP Control
Epifaunal Substrate	8	8	15	17	16	8	17	16	17	13	17
Embeddedness	18	17	14	17	17	0	15	17	18	17	17
Velocity/Depth Regime	16	15	8	19	20	10	16	15	16	14	15
Sediment Deposition	2	3	9	10	8	1	7	7	10	4	13
Channel Flow Status	15	15	15	15	14	18	10	11	15	10	15
Channel Alteration	18	20	15	20	20	19	18	19	19	16	17
Riffle Quality	10	7	6	15	20	1	17	19	19	17	15
Bank Stability L/R	10/8	3/9	9/10	10/3	9/9	9/10	8/9	10/9	9/9	10/6	9/9
Vegetative Protection L/R	2/1	2/3	1/0	1/0	2/1	1/1	3/1	2/1	1/1	1/1	3/1
Riparian Vegetation L/R	9/8	8/10	1/9	10/10	9/10	1/6	7/8	10/10	9/10	2/3	10/9
Score	125	120	112	147	155	85	136	146	153	114	150
Percentage of SHAPP control	83	80	75	98	>100	57	91	97	>100	76	--

20 points possible for each feature; L = Left bank, R = Right bank - 10 points possible for each bank; Bold = below 75 percent threshold.

Table 6
 Stream Habitat Assessment Project Procedure (SHAPP) Features and Scores for
 Village Creek (VC) and Saline Creek (SC) Stations – Comparisons with the SHAPP
 Control Stream and Among Stations

Habitat Assessment Feature	VC 0.2	VC 1.7	SC 3.2	SC 2.0	SC 1.3	SC 1.2	SHAPP Control
Epifaunal Substrate	18	16	17	11	12	11	17
Embeddedness	17	17	15	18	18	16	17
Velocity/Depth Regime	8	11	10	11	6	10	15
Sediment Deposition	12	3	12	4	12	4	13
Channel Flow Status	9	16	9	10	11	8	15
Channel Alteration	16	16	16	16	16	10	17
Riffle Quality	10	11	12	10	10	8	15
Bank Stability L/R	9/9	9/5	6/9	10/10	9/10	9/10	9/9
Vegetative Protection L/R	4/4	1/1	1/6	9/9	2/2	2/5	3/1
Riparian Vegetation L/R	1/1	8/3	1/9	2/9	10/3	3/2	10/9
Score	118	117	123	129	121	98	150
Percentage of SHAPP control	79	78	82	86	81	65	--

Bold = Below 75 percent threshold; L = Left bank, R = Right bank.

Table 7
 Little St. Francis River Stations, Fall 2018 – Individual Metric Values and Scores,
 Macroinvertebrate Stream Condition Index Scores (MSCI), and Biological Support Category by
 Station; Biological Criteria Scoring Table (in gray) Used to Calculate Metric Scores

Station Number	Sample No.	TR	EPTT	BI	SDI	MSCI	Support
21.2 Upstream	18050	80 ₍₃₎	16 ₍₃₎	6.3 ₍₃₎	3.21 ₍₃₎	12	P
21.1 Sweetwater Br.	18049	81 ₍₃₎	18 ₍₃₎	6.8 ₍₃₎	3.30 ₍₃₎	12	P
16.6 City Lake	18061	74 ₍₃₎	14 ₍₃₎	7.3 ₍₃₎	2.31 ₍₃₎	12	P
16.3 Village Cr.	18060	80 ₍₃₎	19 ₍₃₎	6.4 ₍₃₎	3.21 ₍₃₎	12	P
16.0 Saline Cr.	18059	78 ₍₃₎	17 ₍₃₎	6.3 ₍₃₎	3.38 ₍₅₎	14	P
13.7 Spiva Br.	18063	53 ₍₃₎	12 ₍₃₎	7.4 ₍₃₎	1.81 ₍₃₎	12	P
13.0 Mill Cr.	18062	68 ₍₃₎	20 ₍₃₎	6.3 ₍₃₎	2.73 ₍₃₎	12	P
10.4 Plum Cr	18051	83 ₍₃₎	24 ₍₅₎	5.8 ₍₅₎	3.06 ₍₃₎	16	F
3.0 Baptist Camp	18064	85 ₍₃₎	24 ₍₅₎	5.7 ₍₅₎	3.18 ₍₃₎	16	F
0.4 Confluence	18065	85 ₍₃₎	24 ₍₅₎	5.0 ₍₅₎	3.43 ₍₅₎	18	F
Metric Score=5	↔	>86	>23	<5.9	>3.36	20-16	Full
Metric Score=3	↔	86-43	23-11	5.9-7.9	3.36-1.68	14-10	Partial
Metric Score=1	↔	<43	<11	>7.9	<1.68	8-4	Non

Biological criteria scoring table (bottom) developed from BIOREF streams ($n=11$); TR=Taxa Richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index; (#subscript)=individual metric score; **Bold**=less than optimum value and score.

Table 8
 Village Creek (VC) and Saline Creek (SC) Stations, Fall 2018 – Individual Metric Values and
 Scores, Macroinvertebrate Stream Condition Index Scores (MSCI), and Biological Support
 Category by Station; Biological Criteria Scoring Table (in gray) Used to Calculate Metric Scores

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	MSCI	Support
VC 0.2 Upstream	18057	88 ₍₅₎	20 ₍₃₎	6.6 ₍₃₎	3.36 ₍₃₎	14	P
VC 1.7 Shays Cr.	18056	95 ₍₅₎	22 ₍₃₎	6.6 ₍₃₎	3.37 ₍₅₎	16	F
SC 3.2 Upstream	18052	95 ₍₅₎	19 ₍₃₎	6.1 ₍₃₎	3.62 ₍₅₎	16	F
SC 2.0 Goose Cr.	18055	90 ₍₅₎	20 ₍₃₎	6.8 ₍₃₎	3.57 ₍₅₎	16	F
SC 1.3 Unnamed Trib.	18053	60 ₍₃₎	7 ₍₁₎	7.1 ₍₃₎	2.95 ₍₃₎	10	P
SC 1.2 Tollar Br.	18054	66 ₍₃₎	5 ₍₁₎	7.8 ₍₃₎	2.96 ₍₃₎	10	P
Metric Score=5	↔	>86	>23	<5.9	>3.36	20-16	Full
Metric Score=3	↔	86-43	23-11	5.9-7.9	3.36-1.68	14-10	Partial
Metric Score=1	↔	<43	<11	>7.9	<1.68	8-4	Non

Biological criteria scoring table (bottom) developed from BIOREF streams ($n=11$); TR=Taxa Richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index; (#subscript)=individual metric score; **Bold**=less than optimum value and score.

Table 9
 Village Creek and Saline Creek Stations, Spring 2019 – Individual Metric Values and Scores,
 Macroinvertebrate Stream Condition Index Scores (MSCI) and Biological Support Category by
 Station; Biological Criteria Scoring Table (in gray) Used to Calculate Metric Scores

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	MSCI	Support
VC 0.2 Upstream	19028	100 ₍₅₎	26 ₍₃₎	6.0 ₍₃₎	3.32 ₍₃₎	14	P
VC 1.7A Shays Cr.	19026	103 ₍₅₎	25 ₍₃₎	6.2 ₍₃₎	3.58 ₍₃₎	14	P
VC 1.7B Shays Cr.	19027	110 ₍₅₎	26 ₍₃₎	6.0 ₍₃₎	3.48 ₍₃₎	14	P
SC. 3.2 Upstream	19030	113 ₍₅₎	25 ₍₃₎	5.8 ₍₅₎	3.51 ₍₃₎	16	F
SC 2.0 Goose Cr.	19031	123 ₍₅₎	28 ₍₃₎	6.2 ₍₃₎	3.85 ₍₅₎	16	F
SC 1.3 Unnamed Trib.	19033	101 ₍₅₎	22 ₍₃₎	6.2 ₍₃₎	3.33 ₍₃₎	14	P
SC 1.2 Tollar Br.	19032	93 ₍₃₎	23 ₍₃₎	6.1 ₍₃₎	3.50 ₍₃₎	12	P
Metric Score=5	↔	>95	>29	<5.9	>3.61	20-16	Full
Metric Score=3	↔	95-47	29-15	5.9-7.9	3.61-1.81	14-10	Partial
Metric Score=1	↔	<47	<15	>7.9	<1.81	8-4	Non

Biological criteria scoring table (bottom) developed from BIOREF streams ($n=14$); TR=Taxa Richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index; (#subscript)=individual metric score; **Bold**=less than optimum value and score.

Table 10
 Dominant Macroinvertebrate Taxa Percentage (and Rank) for BIOREF and
 Little St. Francis River (LSFR) Stations, Fall 2018

Dominant Taxa	BIOREF	21.2 Upstream	21.1 Sweetwater Br.	16.6 City Lake	16.3 Village Cr.	16.0 Saline Cr.	13.7 Spiva Br.	13.0 Mill Cr.	10.4 Plum Cr.	3.0 Baptist Camp	0.4 Confluence
<i>Stenelmis</i> spp.	7.27 (1)	3.96(7)	0.61(28)	0.50(27)	13.50(2)	4.89(6)	1.24(11)	18.86(2)	15.62(2)	22.05(1)	17.02(1)
<i>Caenis latipennis</i>	6.82 (2)	15.72(1)	13.80(1)	53.76(1)	13.80(1)	10.84(2)	64.60(1)	23.81(1)	9.86(3)	11.80(2)	4.26(4)
<i>Caenis anceps</i>	6.44 (3)	5.22(6)	12.88(2)	--	--	--	--	--	4.65(6)	0.16(55)	--
<i>Hyaella azteca</i>	5.96 (4)	1.53(16)	3.37(10)	4.67(3)	2.85(8)	0.08(60)	4.80(2)	0.67(21)	0.39(28)	0.31(42)	--
<i>Tricorythodes</i> spp.	4.79 (5)	12.38(2)	4.50(6)	0.17(41)	9.60(3)	7.50(4)	1.65(7)	11.74(3)	20.27(1)	9.86(3)	4.26(5)
<i>Maccaffertium mediopunctatum</i>	3.68 (6)	--	--	--	--	--	--	0.34(28)	--	--	--
<i>Tanytarsus</i> spp.	3.66 (7)	7.23(4)	11.55(3)	6.26(2)	9.30(4)	6.19(5)	1.49(8)	1.01(14)	3.55(7)	7.38(4)	10.13(2)
<i>Isonychia bicolor</i>	3.40 (8)	1.95(12)	--	--	0.15(55)	--	--	0.08(51)	0.24(42)	0.85(22)	0.34(41)
<i>Cricotopus/Orthocladius</i>	2.82 (9)	0.21(44)	0.51(32)	0.58(23)	1.13(16)	0.24(42)	--	1.01(15)	0.63(21)	1.32(16)	0.68(32)
Acarina	2.38 (11)*	1.32(19)	3.48(9)	2.67(4)	0.90(19)	0.41(36)	1.41(10)	0.17(38)	0.32(37)	0.78(23)	1.45(17)

Rank = numerical position of dominance in that station; -- = absent from sample; **Bold** = Notable percentage or rank. *Heptageniidae (ranked 10 in BIOREF) was omitted from the DMT list because it is not exclusive of others on the list; Acarina (ranked 11) was included in its place.

Table 11
 Dominant Macroinvertebrate Taxa Percentage (and Rank) for BIOREF,
 Village Creek, and Saline Creek Stations, Fall 2018

Dominant Taxa	BIOREF	VC 0.2 Upstream	VC 1.7 Shays Cr.	SC 3.2 Upstream	SC 2.0 Goose Cr.	SC 1.3 Unnamed Trib.	SC 1.2 Tollar Br.
<i>Stenelmis</i> spp.	7.27 (1)	8.96(3)	7.07(3)	7.54(5)	11.16(1)	0.42(28)	0.37(24)
<i>Caenis latipennis</i>	6.82 (2)	16.34(1)	3.60(8)	8.86 (1)	6.73(4)	0.17(38)	--
<i>Caenis anceps</i>	6.44 (3)	--	--	7.85(4)	3.15(10)	--	--
<i>Hyalella azteca</i>	5.96 (4)	5.47(4)	0.40(42)	8.24 (3)	4.86(5)	--	--
<i>Tricorythodes</i> spp.	4.79 (5)	3.89(7)	1.00(20)	--	2.81(12)	--	--
<i>Maccaffertium mediopunctatum</i>	3.68 (6)	--	--	--	--	--	--
<i>Tanytarsus</i> spp.	3.66 (7)	11.18(2)	21.00(1)	4.51(6)	8.60(2)	11.03(3)	5.12(6)
<i>Isonychia bicolor</i>	3.40 (8)	0.24(48)	0.07(69)	2.41(10)	0.17(56)	--	--
<i>Cricotopus/ Orthocladius</i>	2.82 (9)	0.32(43)	0.13(60)	--	0.77(25)	4.43(6)	0.61(21)
Acarina	2.38 (11)*	1.35(16)	1.07(17)	0.39(40)	0.94(23)	2.59(9)	1.95(12)

Rank = numerical position of dominance in that station; -- = absent from sample; **Bold** = notable percentage or rank.
 *Heptageniidae (ranked 10 in BIOREF) was omitted from the DMT list because it is not exclusive of others on the list; Acarina (ranked 11) was included in its place.

Table 12
 Dominant Macroinvertebrate Taxa Percentage (and Rank) for BIOREF,
 Village Creek, and Saline Creek Stations, Spring 2019

Dominant Taxa	BIOREF	VC 0.2 Upstream	VC 1.7A Shays Cr.	VC 1.7B Shays Cr.	SC 3.2 Upstream	SC 2.0 Goose Cr.	SC 1.3 Unnamed Trib.	SC 1.2 Tollar Br.
<i>Cricotopus/ Orthocladus</i>	8.72 (1)	6.09(4)	6.56(5)	6.74(6)	16.50(1)	11.91(1)	24.94(1)	19.74(1)
<i>Caenis latipennis</i>	6.98 (2)	12.19(3)	5.45(7)	4.67(9)	8.56(3)	9.25(2)	3.14(7)	1.88(12)
<i>Stenelmis</i> spp.	4.69 (3)	5.55(6)	8.46(2)	7.61(4)	5.35(4)	3.15(8)	0.55(31)	0.56(34)
<i>Tanytarsus</i> spp.	4.37 (4)	5.08(7)	9.25(1)	9.08(2)	4.20(5)	3.57(6)	5.33(4)	6.11(3)
<i>Caenis anceps</i>	3.35 (5)	--	0.08(77)	--	--	--	--	--
<i>Stenonema femoratum</i>	3.09 (6)	0.68(21)	0.47(38)	0.40(40)	0.84(27)	0.63(34)	0.47(32)	0.28(48)
<i>Hyalella azteca</i>	2.94 (7)	3.05(8)	0.71(28)	0.67(25)	0.38(43)	1.19(25)	0.08(74)	--
<i>Acentrella</i> spp.	2.35 (8)	0.14(58)	--	--	--	0.28(55)	0.08(75)	--
<i>Polypedilum flavum</i>	2.32 (9)	0.68(22)	0.87(21)	0.73(23)	0.61(34)	0.28(56)	0.24(47)	0.75(29)
<i>Thienemannimyia</i> grp.	2.28 (10)	1.22(14)	2.45(12)	3.20(10)	1.53(16)	1.61(15)	2.35(9)	2.82(9)

Rank = numerical position of dominance in that station; -- = absent from sample; **Bold** = notable percentage or rank.

Table 13
 Physicochemical Water Constituents for Little St. Francis River Stations,
 Fall 2018

Station/ Parameter	21.2 Upstream	21.1 Sweetwater Br.	16.6 City Lake	16.3 Village Cr.	16.0 Saline Cr.	13.7 Spiva Br.	13.0 Mill Cr.	10.4 Plum Cr.	3.0 Baptist Camp	0.4 Confluence
Sample Number	182917	182918	182715	182714	182713	182920	182919	182916	182921	182929
pH (Units)	7.53	7.55	7.50	7.49	7.43	7.59	7.67	7.76	7.88	8.35
Temperature (°C)	19.4	19.3	22.5	20.7	19.8	21.3	21.0	20.4	22.2	23.3
Specific Conductance (µS/cm)	229	227	227	287	379	394	365	352	335	323
Dissolved O ₂	7.4	7.7	7.7	6.8	6.8	6.8	7.4	7.6	8.2	10.1
Discharge (cfs)	6.2	6.7	4.5	7.7	12.4	13.1	19.4	14.9	39.4	32.2
NFR	<5 _{ND}	<5 _{ND}	<5 _{03,10,ND}	<5 _{03,10,ND}	<5 _{03,10,ND}	<5 _{ND}	<5 _{ND}	<5 _{ND}	<5 _{ND}	<5 _{ND}
Turbidity (NTUs)	4.2	4.8	2.7	2.2	2.3	3.7	2.9	2.5	3.8	2.7
Total Nitrogen	0.52	0.48	0.61	0.59	1.65	1.47	1.15	0.95	0.73	0.56
Nitrate+Nitrite as N	0.24	0.22	0.29	0.35	1.57	1.32	1.01	0.82	0.54	0.41
Ammonia as N	0.034 ₀₅	0.031 ₀₅	0.042 ₀₅	<0.02 _{ND}	0.031 ₀₅	0.048 ₀₅	0.054	<0.02 _{ND}	0.073	<0.02 _{ND}
Sulfate	11.0	12.2	11.4	17.1	38.6	36.0	25.5	25.1	19.7	18.1
Chloride	6.53	6.19	6.23	6.45	11.4	11.5	9.47	8.68	8.21	7.57
Total Phosphorus	0.056	0.050	0.049	0.060	0.19	0.16	0.10	0.078	0.065	0.066
Calcium (mg/L)	21.9	21.9	22.3	29.5	39.7	40.5	38.4	37.2	34.6	34.4
Magnesium (mg/L)	13.6	13.5	13.4	17.3	22.4	23.1	21.9	21.4	20.1	20.0
Hardness (mg/L)	111	110	111	145	191	196	186	181	169	168

Units mg/L unless otherwise labeled; *Italics* = exceeding EPA (2000) suggested guidelines criteria thresholds used for comparison: NO₃+NO₂-N >0.239 mg/L; Turbidity >1.425 NTU; TN >0.379 mg/L; TP >0.006625 mg/L. Subscript qualifiers: ND = not detected at reported value; 03 = exceeded holding time; 05 = estimated value, detected below PQL; 10 = laboratory error.

Table 14
Physicochemical Water Constituents for Village Creek (VC) and Saline Creek (SC) Stations,
Fall 2018

Station/ Parameter	VC 0.2A Upstream	VC 0.2B Upstream	VC 1.7 Shays Cr.	SC 3.2 Upstream	SC 2.0 Goose Cr.	SC 1.3 Unnamed Trib.	SC 1.2 Tollar Br.
Sample Number	182914	182915	182913	182909	182912	182911	182910
pH (Units)	7.74	7.73	7.63	7.50	7.56	7.45	7.42
Temperature (°C)	19.9	19.9	19.8	21.5	23.3	22.1	21.3
Specific Conductance (µS/cm)	412.1	412.1	404.0	342.1	334.1	374.7	353.7
Dissolved O ₂	7.7	7.7	7.0	7.0	7.3	7.0	6.6
Discharge (cfs)	1.4	1.5	3.7	8.8	9.7	13.2	20.7
NFR	<5 _{ND}	<5 _{ND}	<5 _{ND}	8.00	6.00	6.00	7.00
Turbidity (NTUs)	1.4	1.2	3.8	<i>13.0</i>	8.2	<i>10.0</i>	<i>11.0</i>
Total Nitrogen	<i>0.53</i>	<i>0.53</i>	<i>0.88</i>	<i>0.89</i>	<i>0.69</i>	<i>0.91</i>	<i>0.79</i>
Nitrate+Nitrite as N	<i>0.30</i>	<i>0.31</i>	<i>0.56</i>	<i>0.41</i>	<i>0.38</i>	<i>0.57</i>	<i>0.48</i>
Ammonia as N	<0.02 _{ND}	0.025 ₀₅	0.060	0.059	0.020 ₀₅	0.068	0.052
Sulfate	27.1	28.3	26.6	11.2	11.7	29.5 ₁₁	25.9
Chloride	6.43	5.29	7.82	8.48	7.22	7.37	6.92
Total Phosphorus	<i>0.023</i>	<i>0.024</i> ₀₈	<i>0.054</i>	<i>0.088</i>	<i>0.067</i>	<i>0.096</i>	<i>0.082</i>
Calcium (mg/L)	44.0	45.2	43.2	37.5	35.5	40.8	37.6
Magnesium (mg/L)	25.8	26.4	24.4	22.8	20.8	23.0	20.9
Hardness (mg/L)	216	222	208	188	174	197	180

Units mg/L unless otherwise labeled; *Italics* = exceeding EPA (2000) suggested guidelines criteria (thresholds) used for comparison: NO₃+NO₂-N >0.239 mg/L; Turbidity >1.425 NTU; TN >0.379 mg/L; TP >0.006625 mg/L. A and B = duplicates; Subscript qualifiers: 05 = estimated value, detected below PQL; 08 = analyte present in blank at <1/2 reported value; 11 = estimated value, matrix interference.

Table 15
 Physicochemical Water Constituents for Village Creek (VC) and Saline Creek (SC) Stations,
 Spring 2019

Station/ Parameter	VC 0.2 Upstream	VC 1.7A Shays Cr.	VC 1.7B Shays Cr.	SC 3.2 Upstream	SC 2.0 Goose Cr.	SC 1.3 Unnamed Trib.	SC 1.2 Tollar Br.
Sample Number	191690	191688	191689	191691	191692	191694	191693
pH (Units)	8.5	8.4	8.3	7.7	7.9	8.1	8.1
Temperature (°C)	11.4	7.9	7.9	6.8	7.8	10.2	9.1
Specific Conductance (µS/cm)	252	284	284	420	225	297	303
Dissolved O ₂	14.05	14.3	14.2	12.73	12.78	12.81	12.70
Discharge (cfs)	10.1	16.6	16.7	9.1	19.3	18.1	24.1
NFR	<5 _{ND}	31.0	30.0	<5 _{ND}	5.00	<5 _{ND}	7.00
Turbidity (NTUs)	3.0	10.0	12.0	4.1	4.3	3.7	6.8
Total Nitrogen	0.78	1.08	0.96	0.96	0.64	0.86	0.89
Nitrate+Nitrite as N	0.78	0.76	0.77	1.06	0.68	0.78	0.82
Ammonia as N	<0.02 _{ND}	<0.02 _{ND}	<0.02 _{ND}	<0.02 _{ND}	<0.02 _{ND}	0.14	0.13
Sulfate	16.9	22.1	23.2 ₀₆	10.4	9.72	42.8	43.0
Chloride	4.08 ₀₅	4.66 ₀₅	4.15 ₀₅	6.21	5.33	5.52	6.82
Total Phosphorus	0.023	0.060	0.051	0.022	0.026	0.025	0.029
Calcium (mg/L)	26.4	28.9	28.9	28.3	25.4	33.8	33.6
Magnesium (mg/L)	15.0	16.0	16.1	16.8	14.9	19.4	19.3
Hardness (mg/L)	128	138	138	140	125	164	163

Units mg/L unless otherwise labeled; *Italics* = exceeding EPA (2000) suggested guidelines criteria thresholds used for comparison: NO₃+NO₂-N >0.239 mg/L; Turbidity >1.425 NTU; TN >0.379 mg/L; TP >0.006625 mg/L. A and B = duplicates. Subscript qualifiers: 05 = estimated value, detected below PQL; 06 = estimated value, QC data outside limits.

Table 16
 Surface Water Dissolved Metals and Hardness as CaCO₃
 at Little St. Francis River Stations, Fall 2018

Station/ Parameter	21.2 Upstream	21.1 Sweetwater Br.	16.6 City Lake	16.3 Village Cr.	16.0 Saline Cr.	13.7 Spiva Br.	13.0 Mill Cr.	10.4 Plum Cr.	3.0 Baptist Camp	0.4 Confluence
Sample Number	182917	182918	182715	182714	182713	182920	182919	182916	182921	182929
Arsenic	0.63 ₀₅	0.69 ₀₅	0.93 ₀₅	0.92 ₀₅	0.75 ₀₅	0.88 ₀₅	0.77 _{05,06}	0.77 ₀₅	0.82 ₀₅	0.90 ₀₅
Barium	63.8	62.8	75.9	88.2	82.0	85.6	82.9	81.6	76.0	72.6
Cadmium	<0.10 _{ND}	<0.10 _{ND}	<0.10 _{ND}	<0.10 _{ND}	<0.10 _{ND}	<0.10 _{ND}	<0.10 _{ND}	<0.10 _{ND}	<0.10 _{ND}	<0.10 _{ND}
Cobalt	<1 _{ND}	<1 _{ND}	<1 _{ND}	<1 _{ND}	2.54 ₀₅	<1 _{ND}	1.08 ₀₅	<1 _{ND}	<1 _{ND}	<1 _{ND}
Copper	1.62	1.66	2.19	1.59	1.95	2.24	1.87	1.91	1.83	1.90
Iron	227	223	14.6	16.8	12.7	12.6	9.84	14.8	18.2	16.6
Lead	2.15	2.15	2.92c	2.35	1.60	2.75	2.07	1.51	1.46	1.66
Manganese	69.4	72.1	55.2	63.8	59.5	71.9	119	35.3	32.7	10.9
Nickel	<0.50 _{ND}	<0.50 _{ND}	0.61 ₀₅	<0.50 _{ND}	30.3	13.5	7.80	4.20	1.43	1.13
Silver	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{06,ND}	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}
Zinc	1.01 ₃₀	1.07 ₃₀	1.42 ₃₀	1.28 ₃₀	3.18 ₃₀	1.96 ₃₀	1.80 ₃₀	1.17 ₃₀	1.21 ₃₀	0.97 ₀₅
Calcium (mg/L)	21.9	21.9	22.3	29.5	39.7	40.5	38.4	37.2	34.6	34.4
Magnesium (mg/L)	13.6	13.5	13.4	17.3	22.4	23.1	21.9	21.4	20.1	20.0
Hardness (mg/L)	111	110	111	145	191	196	186	181	169	168

Units µg/L unless otherwise labeled; **Bold** = above MoDNR WQS, **c** = chronic toxicity threshold; Subscript qualifiers: ND = not detected at reported value; 05 = estimated value, detected below PQL; 06 = estimated value, QC data outside limits; 30 = estimated value, QC biased high.

Table 17
 Surface Water Dissolved Metals and Hardness as CaCO₃
 at Village Creek (VC) and Saline Creek (SC) Stations, Fall 2018

Station	VC 0.2A Upstream	VC 0.2B Upstream	VC 1.7 Shays Cr.	SC 3.2 Upstream	SC 2.0 Goose Cr.	SC 1.3 Unnamed Trib.	SC 1.2 Tollar Br.
Sample Number	182914	182915	182913	182909	182912	182911	182910
Arsenic	0.82 ₀₅	0.82 ₀₅	1.23	0.84 _{06,05}	0.80 ₀₅	0.73 ₀₅	0.65 ₀₅
Barium	102.0	101.0	107.0	91.9	84.0	77.3	70.2
Cadmium	<0.10 _{ND}	<0.10 _{ND}	<0.10 _{ND}	<0.10 _{ND}	<0.10 _{ND}	<0.10 _{ND}	<0.10 _{ND}
Cobalt	<1 _{ND}	<1 _{ND}	<1 _{ND}	<1 _{ND}	<1 _{ND}	19.7	13.9
Copper	1.27	1.30	1.45	1.01	1.11	1.90	2.16
Iron	26.3	26.7	38.8	59.1	53.2	40.2	39.7
Lead	0.57 ₀₅	0.56 ₀₅	1.11	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}	0.62 ₀₅
Manganese	32.9	33.5	72.6	16.0	32.1	81.6	69.2
Nickel	<0.50 _{ND}	<0.50 _{ND}	0.51 ₀₅	<0.50 _{ND}	1.02	48.1	41.1
Silver	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{06,ND}	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}
Zinc	1.48 ₃₀	1.17 ₃₀	1.25 ₃₀	1.37 ₃₀	1.57 ₃₀	2.33 ₃₀	2.58 ₃₀
Calcium (mg/L)	44.0	45.2	43.2	37.5	35.5	40.8	37.6
Magnesium (mg/L)	25.8	26.4	24.4	22.8	20.8	23.0	20.9
Hardness (mg/L)	216	222	208	188	174	197	180

Units µg/L unless otherwise labeled; A and B = duplicates. Subscript qualifiers: ND = not detected at reported value; 05 = estimated value, detected below PQL; 06 = estimated value, QC data outside limits; 30 = estimated value, QC biased high.

Table 18
 Surface Water Dissolved Metals ($\mu\text{g/L}$) and Hardness as CaCO_3
 for Village Creek (VC) and Saline Creek (SC) Stations, Spring 2019

Station	VC #0.2 Upstream	VC #1.7A Shays Cr.	VC #1.7B Shays Cr.	SC #3.2 Upstream	SC #2.0 Goose Cr.	SC #1.3 Unnamed Trib.	SC #1.2 Tollar Br.
Sample Number	191690	191688	191689	191691	191692	191694	191693
Arsenic	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}
Barium	39.9	41.9	42.9	44.8	40.9	40.7	42.4
Cadmium	<0.10 _{ND}	<0.10 _{ND}	<0.10 _{ND}	<0.10 _{ND}	<0.10 _{ND}	<0.10 _{ND}	<0.10 _{ND}
Cobalt	<1 _{ND}	<1 _{ND}	<1 _{ND}	<1 _{ND}	<1 _{ND}	51.9	49.3
Copper	0.69 ₀₅	1.02	1.09	<0.50 _{ND}	0.60 ₀₅	1.24	1.21
Iron	44.4	48.0	35.2	35.2	49.9	38.3	34.8
Lead	<0.50 _{ND}	0.77 ₀₅	0.76 ₀₅	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}
Manganese	9.20	40.0	40.5	10.4	12.4	147	144
Nickel	1.31	4.34	4.27	0.82 ₀₅	1.89	85.8c	82.3c
Silver	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}	<0.50 _{ND}
Zinc	0.74 ₀₅	0.79 ₀₅	0.96 ₀₅	0.87 ₀₅	0.85 ₀₅	3.34	3.01
Calcium (mg/L)	26.4	28.9	28.9	28.3	25.4	33.8	33.6
Magnesium (mg/L)	15.0	16.0	16.1	16.8	14.9	19.4	19.3
Hardness (mg/L)	128	138	138	140	125	164	163

Units $\mu\text{g/L}$ unless otherwise labeled; **Bold** = above MoDNR WQS (MoDNR 2018c), **c** = chronic toxicity threshold (79 $\mu\text{g/L}$); Subscript qualifier: ND = not detected at reported value; 05 = estimated value, detected below PQL.

Table 19

Fine Sediment Character at LSFR Stations: Total Recoverable Metals Concentrations (mg/kg), PEC, (PEQ), Σ PEQ, and Mean PEQ

Station Sample No.	Arsenic (PEQ)	Cadmium (PEQ)	Cobalt (PEQ)	Copper (PEQ)	Lead (PEQ)	Nickel (PEQ)	Silver (PEQ)	Zinc (PEQ)	TOC	Σ PEQ _{Cd, Pb, Zn}	Mean PEQ _{all}
21.2A 182692 Upstream	3.53 (0.11)	<0.100 _{ND} (N/A)	10.5 (N/A)	7.31 (0.05)	129.0 (1.01)	12.2 (0.25)	<0.250 _{ND} (N/A)	8.86 (0.02)	2650	1.03	0.21
21.2B 182693 Upstream	4.63 (0.14)	0.129 _{05,11} (0.03)	12.6 (N/A)	27.40 (0.18)	90.8 (0.71)	14.0 (0.29)	<0.250 _{ND} (N/A)	10.10 (0.02)	6340	0.76	0.19
21.1 182694 Sweetwater Br.	9.92 (0.30)	0.458 _{05,11} (0.09)	59.1 (N/A)	241.00 (1.62)	15500.0 ₀₉ (121.09)	61.9 (1.27)	0.909 (0.41)	37.80 (0.08)	12200	121.26	17.84
16.6 182698 City Lake	9.31 (0.28)	0.151 _{05,11} (0.03)	27.5 (N/A)	21.00 (0.14)	1520.0 (11.87)	25.7 (0.53)	0.424 ₀₅ (0.19)	34.20 (0.07)	18300	11.97	1.87
16.3A 182699 Village Cr.	11.30 (0.34)	0.151 _{05,11} (0.03)	18.1 (N/A)	13.30 (0.09)	703.0 (5.49)	20.9 (0.43)	<0.250 _{ND} (N/A)	24.50 (0.05)	15400	5.57	0.92
16.3B 182700 Village Cr. (Dup.)	14.30 (0.43)	0.247 _{05,11} (0.05)	25.1 (N/A)	16.90 (0.11)	1190.0 (9.30)	31.3 (0.64)	0.408 ₀₅ (0.19)	34.10 (0.07)	9260	9.42	1.54
16.0 182701 Saline Cr.	16.20 ₀₉ (0.49)	0.210 _{05,11} (0.04)	30.9 ₁₄ (N/A)	18.10 ₁₄ (0.12)	741.0 (5.79)	39.8 (0.82)	0.316 ₀₅ (0.14)	39.50 (0.09)	14400	5.92	1.07
13.7 182709 Spiva Br.	15.50 (0.47)	0.155 _{05,11} (0.03)	75.2 (N/A)	25.6 (0.17)	678.0 (5.30)	89.0 (1.83)	0.293 ₀₅ (0.13)	36.40 (0.08)	10200	5.41	1.14
13.2 182695 At Mill Cr. confluence	33.50 (1.01)	0.288 _{05,11} (0.06)	157.0 (N/A)	37.70 (0.25)	1030.0 (8.05)	180.0 (3.70)	0.646 (0.29)	56.00 (0.12)	43500	8.23	1.93
13.0 182696 DS Mill Cr.	19.20 (0.58)	0.246 _{05,11} (0.05)	67.3 (N/A)	29.40 (0.20)	1080.0 (8.44)	81.6 (1.68)	<0.250 _{ND} (N/A)	55.80 (0.12)	20800	8.61	1.58
10.4 182702 Plum Cr.	10.10 (0.31)	0.137 _{05,11} (0.03)	42.7 (N/A)	16.00 (0.11)	440.0 (3.44)	53.1 (1.09)	<0.250 _{ND} (N/A)	36.10 (0.08)	6680	3.55	0.72
3.0 182710 Baptist Camp	4.22 (0.13)	<0.100 _{ND} (N/A)	22.3 (N/A)	7.93 (0.05)	121.0 (0.95)	31.0 (0.64)	<0.250 _{ND} (N/A)	24.7 (0.05)	2030	1.00	0.26
0.4 182711 Confluence	5.50 (0.17)	<0.100 _{ND} (N/A)	24.7 (N/A)	6.94 (0.05)	96.1 (0.75)	35.5 (0.73)	<0.250 _{ND} (N/A)	24.7 (0.05)	<815	0.80	0.25
Castor R. 38.0 182697 Control	15.70 ₀₉ (0.47)	0.200 _{05,11} (0.04)	6.6 (N/A)	8.03 (0.05)	37.3 (0.29)	15.8 ₂₉ (0.33)	<0.250 _{ND} (N/A)	52.20 (0.11)	1110	0.44	0.18
PEC Limit	33.0	4.98	N/A	149	128	48.6	2.2*	459	--	≥7.92	T₁₀≥1.11 n=7

Units are mg/kg; TOC = total organic carbon; PEC=probable effects concentration (MacDonald et al. 2000); **Bold**=above PEC; PEQ = probable effects quotient=metal value/PEC; Mean PEQ = Σ PEQ/#metals; Σ PEQ = sum of PEQs for Cd, Pb, Zn; T₁₀ = toxicity threshold (MacDonald et al. 2009). Subscript qualifiers: 05 = estimated value, detected below PQL, 09 = sample was diluted during analysis, 11 = estimated value, matrix interference, 14 = Estimated value, non-homogeneous sample, 29 = Estimated value, QC data biased low; * = MacDonald and MacFarlane (1999) in Wisconsin DNR (2003). "Less than" values were below laboratory detection limits.

Table 20
Fine Sediment Character at Village Creek (VC) and Saline Creek (SC) Stations:
Total Recoverable Metals Concentrations (mg/kg), PEC, (PEQ), Σ PEQ, and Mean PEQ

Station Sample No.	Arsenic (PEQ)	Cadmium (PEQ)	Cobalt (PEQ)	Copper (PEQ)	Lead (PEQ)	Nickel (PEQ)	Silver (PEQ)	Zinc (PEQ)	TOC	Σ PEQ _{Cd, Pb, Zn}	Mean PEQ _{all}
VC 0.2 182707 Upstream	63.0 (1.9)	0.462 _{05,11} (0.09)	31.1 (N/A)	26.2 (0.17)	125.0 (0.98)	36.4 (0.75)	0.268 ₀₅ (0.12)	68.00 (0.15)	4420	1.22	0.59
VC 1.7 182708 Shays Cr.	37.5 (1.14)	0.343 _{05,11} (0.07)	24.5 (N/A)	24.1 (0.16)	203.0 (1.59)	37.3 (0.77)	<0.250 _{ND} (N/A)	44.20 (0.10)	6090	1.76	0.55
SC 3.2 182703 Upstream	22.3 (0.67)	0.224 _{05,11} (0.04)	15.0 (N/A)	10.4 (0.07)	30.8 (0.24)	15.7 (0.32)	<0.250 _{ND} (N/A)	38.60 (0.08)	1710	0.36	0.20
SC 2.0 182704 Goose Cr.	15.7 (0.47)	0.217 _{05,11} (0.04)	72.1 (N/A)	11.8 (0.08)	34.5 (0.27)	80.9 (1.66)	<0.250 _{ND} (N/A)	47.90 (0.10)	5130	0.41	0.37
SC 1.3 182705 Unnamed Trib.	12.1 (0.37)	0.266 _{05,11} (0.05)	267.0 (N/A)	105.0 (0.70)	156.0 (1.22)	216.0 (4.44)	<0.250 _{ND} (N/A)	74.70 (0.16)	4040	1.43	0.99
SC 1.2 182706 Tollar Br.	17.1 ₀₉ (0.52)	1.09 ₁₁ (0.22)	317.0 (N/A)	156.0 (1.05)	315.0 (2.46)	306.0 (6.30)	0.419 ₀₅ (0.19)	130.00 (0.28)	4130	2.96	1.57
Castor R. 38.0 182697 Control	15.7 ₀₉ (0.47)	0.200 _{05,11} (0.04)	6.6 (N/A)	8.03 (0.05)	37.3 (0.29)	15.8 ₂₉ (0.33)	<0.250 _{ND} (N/A)	52.20 (0.11)	1110	0.44	0.18
PEC Limit	33.0	4.98	N/A	149	128	48.6	2.2*	459	--	≥7.92	T ₁₀ ≥1.11 n=7

Units are mg/kg; TOC = total organic carbon; PEC=probable effects concentration (MacDonald et al. 2000); **Bold**=above PEC; PEQ = probable effects quotient=metal value/PEC; Mean PEQ = Σ PEQ/#metals; Σ PEQ = sum of PEQs for Cd, Pb, Zn; T₁₀ = toxicity threshold (MacDonald et al. 2009). Subscript qualifiers: 05 = estimated value, detected below PQL, 09 = sample was diluted during analysis, 11 = estimated value, matrix interference; 29 = Estimated value, QC data biased low; * = MacDonald and MacFarlane (1999) in Wisconsin DNR (2003). “Less than” values were below laboratory detection limits.

Figure 5: Arsenic (mg/kg) per LSFR Station

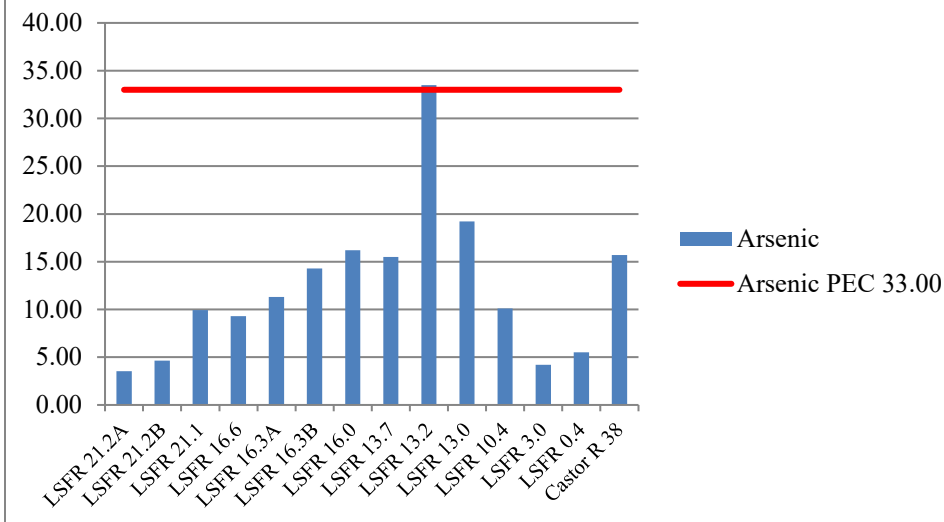
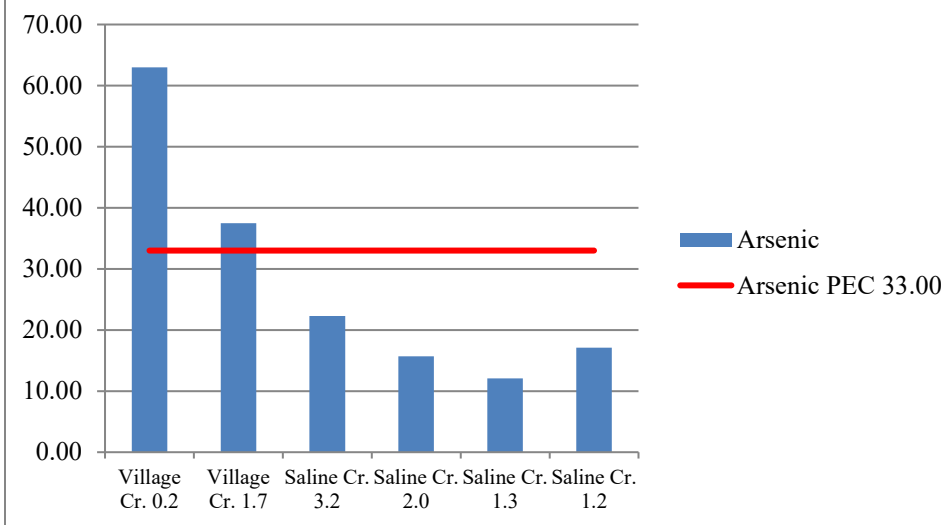


Figure 6: Arsenic (mg/kg) per Tributary Station



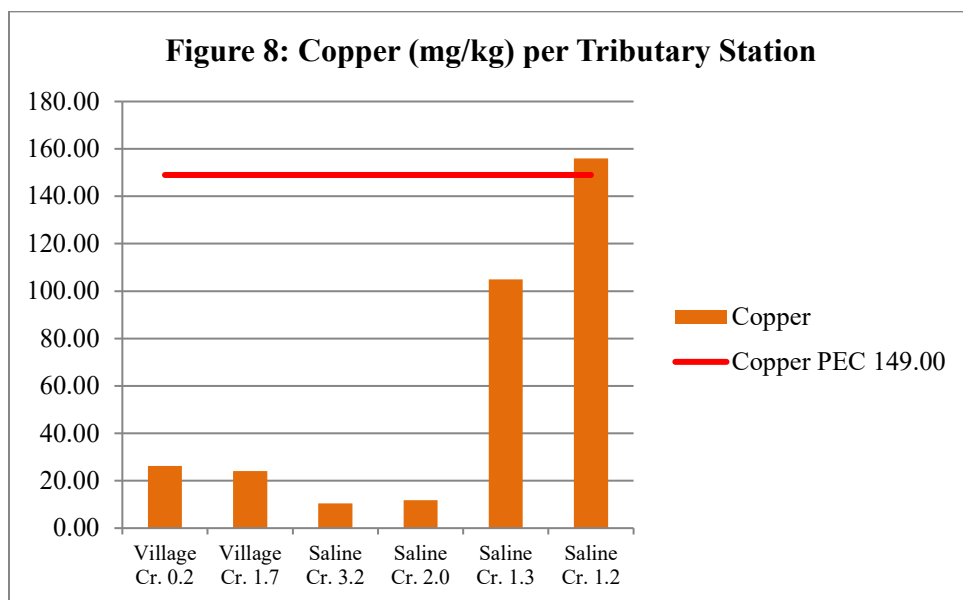
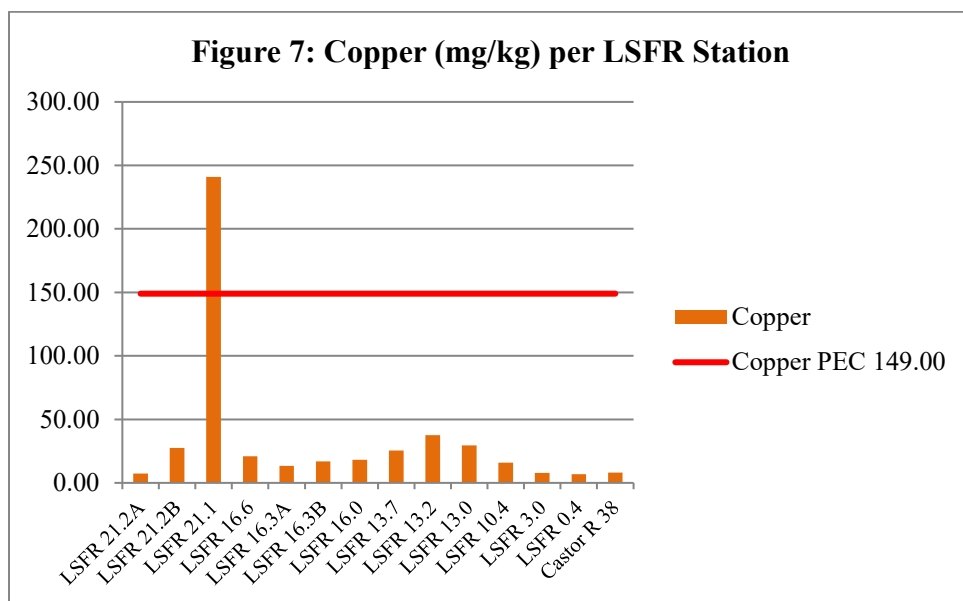


Figure 9: Lead (mg/kg) per LSFR Station

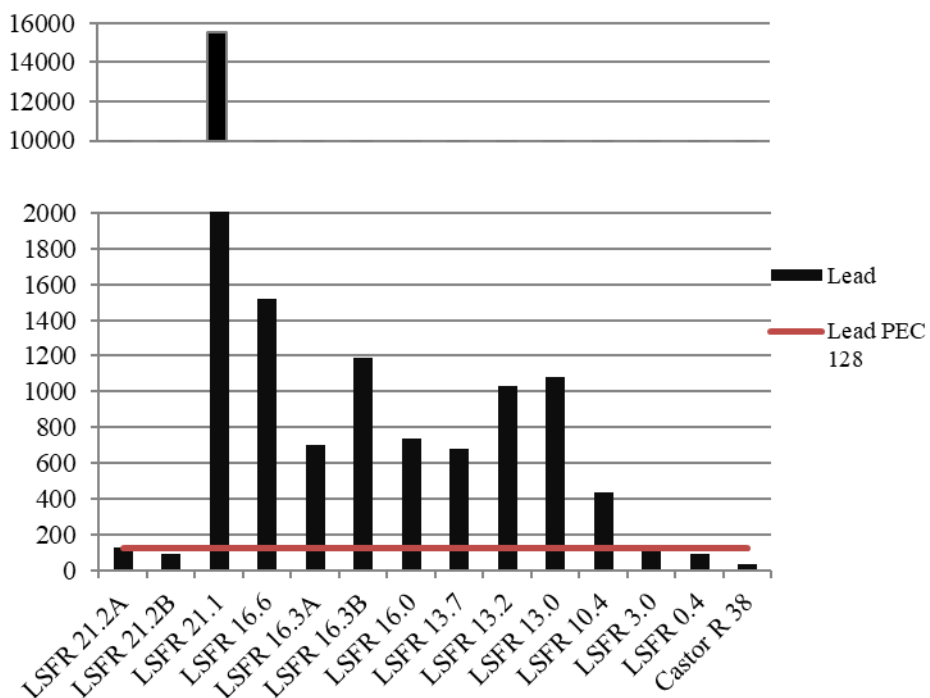


Figure 10: Lead (mg/kg) per Tributary Station

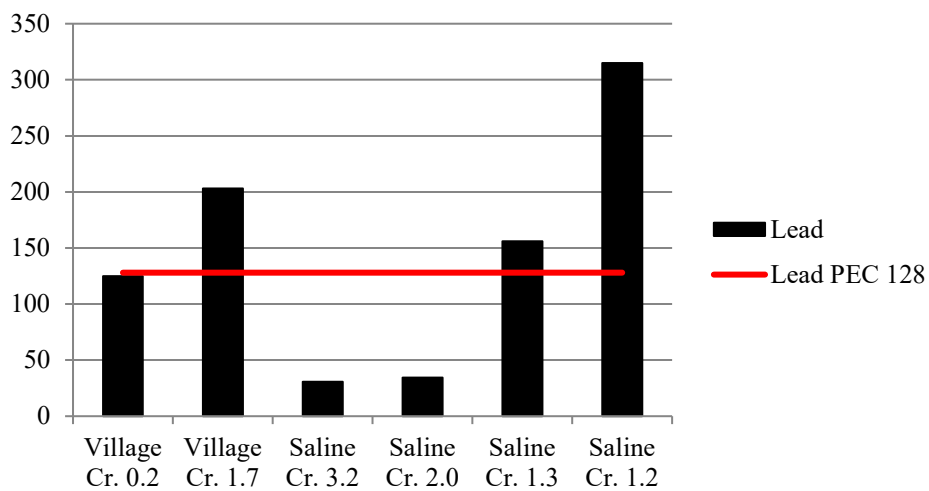


Figure 11: Nickel (mg/kg) per LSFR Station

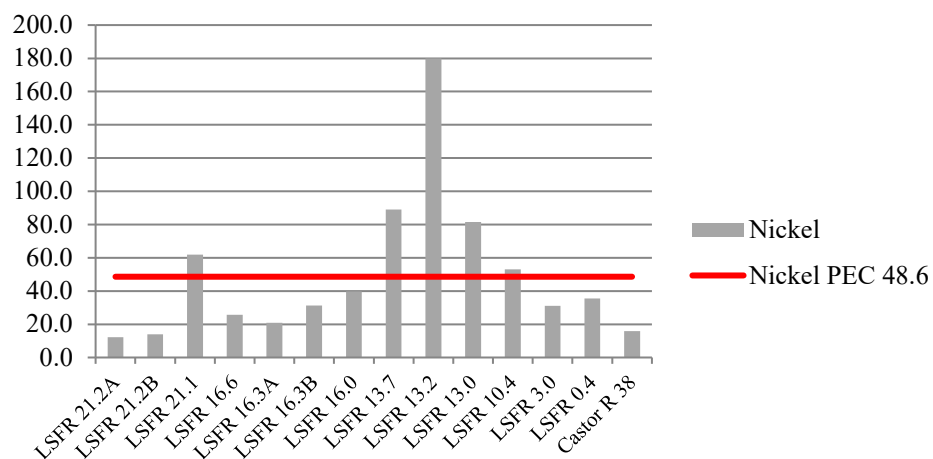
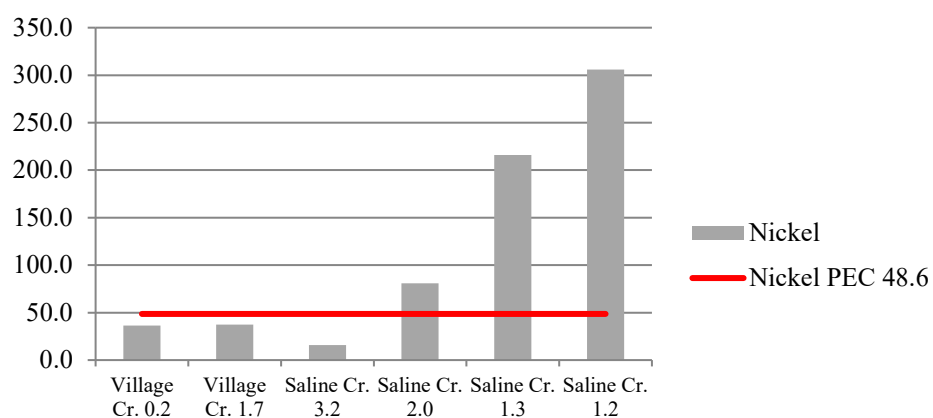


Figure 12: Nickel (mg/kg) per Tributary Station



4.0 Conclusions

The project objectives have been addressed. Stream habitat, the macroinvertebrate community, and physicochemical water quality have been assessed. Dissolved metals concentrations in the surface water and total metals concentrations associated with the fine sediment (i.e. metals character) have been identified.

Testing of the null hypotheses resulted in the following:

- 1) Stream habitat quality will be comparable to the stream habitat control at all stations.

This null hypothesis was rejected for LSFR 13.7, downstream from Spiva Branch, and SC 1.2, downstream from Tollar Branch.

- 2) MSCI scores will indicate that LSFR, VC, and SC will be fully supporting of the beneficial use – for the protection of WWH, and individual biological metric scores will be within the optimum scoring range of wadeable/perennial reference stream biological criteria during the fall and spring seasons.

The null hypothesis for the fully supporting criterion was rejected for:

- All LSFR stations were partially supporting except three farthest downstream (LSFR 10.4, LSFR 3.0, and LSFR 0.4), which had fully supporting MSCI scores;
- VC 0.2 was partially supporting in both seasons;
- VC 1.7 was fully supporting in fall and partially supporting in spring;
- SC stations downstream of Unnamed Tributary (SC 1.3 and SC 1.2) were partially supporting in both seasons.

The null hypothesis suggesting all individual metrics values will be within the optimal range was rejected for all stations in LSFR (fall), VC and SC in both seasons.

- 3) DMT (Secondary metrics) will indicate that macroinvertebrate communities in LSFR, VC, and SC are similar to BIOREF stream communities.

The null hypothesis was rejected for all LSFR, VC, and SC stations.

- 4) Physicochemical water quality parameters will be within acceptable limits as specified in Missouri's Water Quality Standards, and will not be notable using suggested guidelines.

The null hypothesis for WQS (MoDNR 2018c) was not rejected for all stations. Physicochemical parameters met water quality standards.

The null hypothesis for notable parameters based on EPA (2000) suggested guidelines was rejected because:

- Turbidity, total nitrogen, nitrate+nitrite as N, and total phosphorus exceeded EPA (2000) suggested guidelines at all LSFR stations.
 - Total nitrogen, nitrate+nitrite as N, and total phosphorus consistently exceeded EPA (2000) suggested guidelines at both VC stations. Turbidity exceeded guidelines downstream of Shays Creek (VC 1.7) during both seasons and upstream of Shays Creek (VC 0.2) only in spring.
 - Turbidity, total nitrogen, nitrate+nitrite as N, and total phosphorus consistently exceeded EPA (2000) suggested guidelines at all SC stations.
- 5) Dissolved metals in the surface water at stations will be within acceptable hardness-dependent limits outlined in Missouri's WQS (MoDNR 2018c) in LSFR, VC, and SC.

The null hypothesis was rejected because:

- Dissolved lead exceeded WQS chronic toxicity threshold in LSFR 16.6, downstream of Fredericktown City Lake.
- Dissolved nickel exceeded WQS chronic toxicity threshold at SC 1.3 (downstream of Unnamed Tributary) and SC 1.2 (downstream of Tollar Branch) in spring.

The null hypothesis was not rejected for both VC stations in fall and spring, and SC stations in fall.

- 6) Benthic fine sediment metals (i.e. arsenic, cadmium, copper, lead, nickel, silver, or zinc) concentrations will be below potentially toxic threshold levels in LSFR, VC, and SC stations.

The hypothesis was rejected at all but the two farthest downstream LSFR stations (LSFR 3.0 and LSFR 0.4) because:

- Lead exceeded its PEC at the eight upstream stations, which included LSFR 21.2 downstream to LSFR 10.4.
- Nickel exceeded the PEC downstream of Sweetwater Branch (LSFR 21.1), Spiva Branch (LSFR 13.7), at the Mill Creek confluence (LSFR 13.2), downstream of Mill Creek (LSFR 13.0), and downstream of Plum Creek (LSFR 10.4).
- Arsenic exceeded its PEC at the Mill Creek confluence (LSFR 13.2).

The hypothesis was rejected for both VC stations because:

- Arsenic exceeded the PEC at VC 0.2 and VC 1.7.
- Lead exceeded the PEC at VC 1.7.

The hypothesis was rejected for the three downstream SC stations, which included downstream of Goose Creek (SC 2.0), Unnamed Tributary (SC 1.3), and Tollar Branch (SC 1.2) because:

- Nickel exceeded the PEC at SC 2.0, SC 1.3, and SC 1.2.
- Lead exceeded its PEC at SC 1.3 and SC 1.2.
- Copper exceeded its PEC at SC 1.2.

5.0 Recommendations

- 1) Biological assessments and/or fine sediment metal characterization studies should be conducted in the specific areas of interest to identify conditions and sources.
 - LSFR – include mainstem LSFR upstream of the study area (LSFR 21.2), Sweetwater Branch (21.1), tributaries upstream of Fredericktown City Lake (LSFR 16.6) not sampled in this project, tributaries upstream of the Old Highway 67 bridge (LSFR 13.7 and 13.2) including Spiva Branch, and also Mill Creek (LSFR 13.0).
 - VC – include upstream of VC 0.2 to identify conditions and sources, as well as downstream of VC 1.7 to identify the extent of the effects in VC.
 - SC – include Goose Creek (SC 2.0), Unnamed Tributary (SC 1.3), Tollar Branch (SC 1.2), as well as other tributaries of SC within the study area, and instream below the study area to identify the extent of effects in SC.
- 2) Fredericktown City Lake discharge water should be monitored for dissolved metals, and total metals in sediment to further identify conditions and substantial sources to LSFR.
- 3) Instream fine sediment metals deposits should be addressed to prevent potential sediment pulses from moving into fully supporting areas of LSFR.
- 4) Sediment and total metals should be monitored at LSFR 10.4 (Thompson Ford Conservation Area), LSFR 3.0 (Baptist Camp), and LSFR 0.4 (upstream of the St. Francis River confluence) to identify trends.
- 5) Heavy metals studies should be conducted in St. Francis River to determine if it is the recipient of mine-related material once removed from LSFR.

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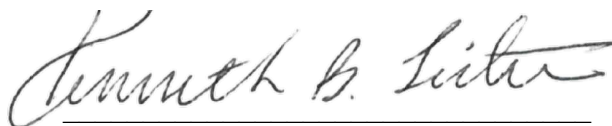
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Appendix A

Macroinvertebrate Bench Sheet Report: Fredericktown Area, Part 2: Little St. Francis River (fall only), Village Creek, and Saline Creek Stations, Madison County, Missouri Fall 2018 – Spring 2019

**Grouped by season and stream (stations - upstream to downstream);
CS = Course Substrate, NF = Non-Flow, RM = Rootmat**

Macroinvertebrate Bench Sheet Report			
Sep 24, 2018 Little St. Francis River - [2854_21.2] - 18050			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina	1	1	17
AMPHIPODA			
Hyaella azteca	1	2	19
BASOMMATOPHORA			
Ancylidae	5		
Menetus		1	14
Physella	1		
COLEOPTERA			
Ancyronyx variegatus			2
Berosus			1
Dubiraphia	1	3	49
Helichus lithophilus			2
Macronychus glabratus			1
Microcylloepus pusillus	34		
Scirtidae		1	1
Stenelmis	51	4	2
DECAPODA			
Cambarus diogenes			*
Faxonius luteus	*		
DIPTERA			
Ablabesmyia	1	21	8
Anopheles		1	
Ceratopogoninae			1
Chironomidae		1	
Cladopelma		3	
Cladotanytarsus		6	
Clinotanytus		1	1
Corynoneura			1
Cricotopus bicinctus	3	1	
Cricotopus/Orthocladius	2		1
Cryptochironomus		4	
Cryptotendipes		1	
Dicrotendipes		25	
Endochironomus			4
Glyptotendipes			7
Hexatoma	2	*	
Labrundinia	1	3	7
Microtendipes		2	
Paralauterborniella		2	
Paratanytarsus		3	3
Paratendipes		1	

Polypedilum aviceps	1		
Polypedilum flavum	84		
Polypedilum halterale grp		1	
Polypedilum illinoense grp	8	2	6
Procladius		3	
Rheocricotopus	1		
Rheotanytarsus	147	1	3
Simulium	23		
Stempellinella	3	4	16
Tanytarsus	16	56	32
Thienemanniella	4	1	
Thienemannimyia grp	3		
Tipula		2	
Tribelos		5	5
Xenochironomus			1
EPHEMEROPTERA			
Caenis anceps	39	36	
Caenis latipennis	41	157	28
Centroptilum		4	
Heptageniidae		2	
Isonychia bicolor	28		
Proclaeon		1	
Stenacron	4	1	
Stenonema femoratum		5	1
Stenonema pulchellum	7		
Tricorythodes	174	1	3
LUMBRICINA			
Lumbricina	2		
MEGALOPTERA			
Corydalus	*		
Sialis		*	
ODONATA			
Argia		2	7
Enallagma			20
Gomphidae		3	
Macromia		*	*
Perithemis			1
TRICHOPTERA			
Cheumatopsyche	29		
Chimarra	22		
Helicopsyche	6		
Oecetis		1	
Polycentropus		1	3
Triaenodes			17
TRICLADIDA			
Planariidae	6		4

TUBIFICIDA			
Branchiura sowerbyi		4	
Tubificinae	1	4	
VENEROIDA			
Corbicula	9	4	
Pisidiidae	1		

Macroinvertebrate Bench Sheet Report			
Sep 24, 2018 Little St. Francis River - [2854_21.1] - 18049			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina	1	4	29
AMPHIPODA			
Hyaella azteca	2	1	30
BASOMMATOPHORA			
Ancylidae			1
Menetus		1	8
Physella			2
COLEOPTERA			
Ancyronyx variegatus			7
Berosus		*	2
Dubiraphia	3	4	45
Macronychus glabratus		2	4
Psephenus herricki	*	1	
Scirtidae			1
Stenelmis	3	2	1
DIPTERA			
Ablabesmyia	18	23	8
Ceratopogoninae		6	3
Chironomidae	1	2	3
Chironomus		9	
Chrysops			1
Cladopelma		1	
Cladotanytarsus	1	21	
Corynoneura	1		
Cricotopus bicinctus	1		
Cricotopus/Orthocladius	2	1	2
Cryptochironomus	3	5	
Cryptotendipes		2	
Dicrotendipes	7	12	2
Endochironomus			14
Glyptotendipes		2	13
Labrundinia	1		3
Microtendipes			2
Nanocladius			2
Nilothauma	2		
Paralauterborniella		1	
Paratanytarsus	3	4	
Paratendipes		1	1
Phaenopsectra	1		7
Polypedilum halterale grp		3	
Polypedilum illinoense grp	7	1	1

Polypedilum scalaenum grp		1	
Procladius		3	
Pseudochironomus		1	
Rheotanytarsus	7		1
Stempellina		5	
Stempellinella	19	6	15
Stenochironomus			1
Stictochironomus		3	
Tanytarsus	29	43	41
Thienemanniella		1	
Thienemannimyia grp	1		
Tribelos		21	17
Xenochironomus			4
EPHEMEROPTERA			
Apobaetis		1	1
Caenis anceps	99	26	1
Caenis latipennis	59	63	13
Centroptilum		2	
Eurylophella bicolor		1	
Leptophlebiidae	2		
Plauditus	1		
Proclaeon	2		
Stenacron		1	1
Stenonema femoratum	4	2	
Tricorythodes	40		4
ODONATA			
Argia	1	1	5
Dromogomphus			*
Enallagma			17
Epitheca (Epicordulia)			*
Gomphidae		1	2
Libellula			*
Macromia			1
Perithemis		1	
Progomphus obscurus		1	
TRICHOPTERA			
Hydroptila	1		
Mystacides		3	
Nectopsyche pavida		4	
Nyctiophylax			1
Oecetis	1	10	3
Polycentropus			3
Triaenodes			5
TUBIFICIDA			
Branchiura sowerbyi	7	4	
Tubificinae	1	2	
VENEROIDA			

Corbicula		*	
Pisidiidae		3	

Macroinvertebrate Bench Sheet Report			
Oct 01, 2018 Little St. Francis River - [2854_16.6] - 18061			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina	3		29
AMPHIPODA			
Hyaella azteca	2	1	53
BASOMMATOPHORA			
Ancylidae	2		
Menetus			15
COLEOPTERA			
Berosus	2		3
Dubiraphia		7	15
Macronychus glabratus		1	
Microcylloepus pusillus			1
Scirtidae	2		6
Stenelmis	4	2	
DIPTERA			
Ablabesmyia	5	5	4
Anopheles			1
Ceratopogoninae		3	1
Chironomidae			1
Chironomus		7	
Cladopelma		2	
Cladotanytarsus		1	
Clinotanytus			4
Cricotopus bicinctus	2		
Cricotopus/Orthocladius	1		6
Cryptochironomus		2	
Dicrotendipes	1	4	3
Endochironomus			4
Forcipomyiinae			1
Glyptotendipes			16
Hexatoma	*		
Labrundinia		1	8
Microtendipes			1
Nanocladius	1		
Nilothauma		1	
Paratanytarsus	1		3
Phaenopsectra		3	4
Polypedilum halterale grp		20	
Polypedilum illinoense grp	5		11
Polypedilum trigonum			1
Pseudochironomus	3	1	
Rheotanytarsus	2		

Stempellinella	11	3	6
Stenochironomus			1
Stictochironomus		1	1
Tanytarsus	31	21	23
Thienemanniella	2		2
Thienemannimyia grp	1		
Tribelos		1	3
Xenochironomus			2
Zavrelia		1	1
EPHEMEROPTERA			
Apobaetis		3	
Caenis latipennis	470	158	16
Callibaetis			1
Centropilum	6	3	3
Hexagenia limbata		2	
Leptophlebiidae	1		
Stenacron	19		
Stenonema femoratum	19	5	
Tricorythodes	2		
MEGALOPTERA			
Sialis	*	1	
ODONATA			
Argia	3		6
Corduliidae			1
Enallagma			27
Epitheca (Tetragoneuria)			1
Gomphidae		1	
Ischnura			2
Libellulidae		1	
Macromia			*
Perithemis			*
TRICHOPTERA			
Cheumatopsyche	1		
Hydroptila	1		
Oecetis		3	4
Polycentropus	3	6	
Triaenodes			1
TUBIFICIDA			
Aulodrilus	1		
Branchiura sowerbyi	7	9	
Tubificinae	6	3	
VENEROIDA			
Corbicula	3	*	

Macroinvertebrate Bench Sheet Report			
Oct 01, 2018 Little St. Francis River - [2854_16.3] - 18060			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina		2	10
AMPHIPODA			
Hyaella azteca		3	35
BASOMMATOPHORA			
Menetus	1	1	5
COLEOPTERA			
Berosus	2	2	
Dubiraphia		7	23
Helichus fastigiatus			1
Macronychus glabratus			8
Microcylloepus pusillus	1	1	2
Scirtidae			1
Stenelmis	176	1	3
DIPTERA			
Ablabesmyia	1	11	14
Ceratopogoninae			1
Chironomidae	2	1	3
Chironomus		4	
Cladopelma		1	
Cladotanytarsus	2	5	
Corynoneura	2	1	1
Cricotopus bicinctus			1
Cricotopus/Orthocladius	7	2	6
Cryptochironomus	2	4	
Dicrotendipes		3	2
Endochironomus			1
Eukiefferiella	1		
Glyptotendipes			2
Hexatoma	5		
Labrundinia		1	8
Nanocladius		10	2
Parachironomus			3
Parakiefferiella		3	
Paralauterborniella		1	
Paratanytarsus		1	10
Phaenopsectra			6
Polypedilum flavum	75	1	3
Polypedilum halterale grp		2	
Polypedilum illinoense grp		2	28
Polypedilum scalaenum grp	1		
Procladius		2	

Pseudochironomus		1	
Rheotanytarsus	8	6	22
Simulium	4		
Stempellina		1	
Stempellinella	2	3	1
Stictochironomus		3	
Tabanus	*		
Tanytarsus	4	52	68
Thienemanniella		1	1
Thienemannimyia grp	3		
EPHEMEROPTERA			
Acerpenna	2		
Apobaetis		1	1
Baetis	16		
Caenis latipennis	30	131	23
Centroptilum		3	3
Isonychia bicolor	2		
Leptophlebiidae	1		
Stenacron	3	1	
Stenonema femoratum	2	7	1
Stenonema pulchellum	3		
Tricorythodes	112	6	10
HEMIPTERA			
Ranatra buenoi			1
LUMBRICINA			
Lumbricina	4		
MEGALOPTERA			
Corydalus	2	1	
ODONATA			
Argia	*	*	11
Dromogomphus		*	
Enallagma			15
Gomphidae		1	
Macromia		1	*
Perithemis			1
Somatochlora		*	
PLECOPTERA			
Perlidae	11		
TRICHOPTERA			
Cheumatopsyche	95		1
Chimarra	28		
Helicopsyche	1		
Hydroptila			3
Oecetis	2		4
Polycentropus		2	
Triaenodes			3

TRICLADIDA			
Planariidae	13		
TUBIFICIDA			
Branchiura sowerbyi	6	8	2
Tubificinae	2	3	1
VENEROIDA			
Corbicula	35	9	

Macroinvertebrate Bench Sheet Report			
Oct 01, 2018 Little St. Francis River - [2854_16.0] - 18059			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina		3	2
AMPHIPODA			
Hyaella azteca		1	
BASOMMATOPHORA			
Menetus	2	1	
Physella	1		1
COLEOPTERA			
Berosus	6	6	9
Dubiraphia		9	18
Helichus lithophilus			1
Macronychus glabratus			4
Microcylloepus pusillus		1	27
Psephenus herricki	*		
Stenelmis	41	13	6
DIPTERA			
Ablabesmyia	2	22	7
Ceratopogoninae		3	1
Chironomidae	1	1	
Chironomus		2	
Cladopelma		3	
Cladotanytarsus	1	5	1
Clinotanytus		1	
Corynoneura		1	
Cricotopus bicinctus			3
Cricotopus/Orthocladus	3		
Cryptochironomus		13	
Dicrotendipes		15	1
Glyptotendipes	1		
Labrundinia		2	8
Nanocladius		1	
Paracladopelma		2	
Parakiefferiella		2	
Paralauterborniella		1	
Paratanytarsus		2	7
Paratendipes		1	
Phaenopsectra			3
Polypedilum flavum	99		3
Polypedilum halterale grp		9	1
Polypedilum illinoense grp	6	4	6
Polypedilum scalaenum grp		1	
Procladius		1	

Rheotanytarsus	6		19
Simulium			1
Stempellinella	2	8	
Stictochironomus		16	
Tanytarsus	9	51	16
Thienemanniella			2
Thienemannimyia grp	1		
Tribelos		2	5
EPHEMEROPTERA			
Apobaetis		16	
Baetis	18		
Caenis latipennis	108		25
Centropilum		7	
Hexagenia		2	
Leptophlebiidae	1		
Proclaeon	1		
Stenonema femoratum	5		
Stenonema pulchellum	2		
Tricorythodes	82		10
ISOPODA			
Caecidotea (Blind & Unpigmented)	26	1	
LUMBRICINA			
Lumbricina		1	
MEGALOPTERA			
Corydalus	*		
ODONATA			
Argia	3		7
Calopteryx			1
Enallagma		1	25
Erythemis			1
Gomphidae		7	
Hetaerina			5
Macromia		1	
Perithemis			*
TRICHOPTERA			
Cheumatopsyche	142	3	3
Chimarra	10		
Hydroptila		1	3
Mystacides	1	1	1
Oecetis	4		40
Polycentropus		2	
Triaenodes			38
TRICLADIDA			
Planariidae	6	2	1
TUBIFICIDA			
Branchiura sowerbyi		8	

Tubificinae	3	8	1
VENEROIDA			
Corbicula	52	2	1
Pisidiidae			2

Macroinvertebrate Bench Sheet Report			
Oct 02, 2018 Little St. Francis River - [2854_13.7] - 18063			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina	2	1	14
AMPHIPODA			
Hyaella azteca		1	57
BASOMMATOPHORA			
Helisoma		*	
Lymnaeidae			1
Menetus		1	
Physella	2		2
COLEOPTERA			
Ancyronyx variegatus			5
Berosus	8	11	24
Dubiraphia	1	2	24
Helichus lithophilus			1
Macronychus glabratus			14
Neoporus			1
Psephenus herricki	3	1	2
Scirtidae			5
Stenelmis	2	6	7
DIPTERA			
Ablabesmyia	5	5	8
Ceratopogoninae			1
Chironomus			1
Cryptochironomus		1	
Cryptotendipes		2	
Dicrotendipes		4	2
Paratanytarsus	1		1
Polypedilum halterale grp		3	
Polypedilum illinoense grp		1	26
Rheotanytarsus	1		2
Stempellinella	1	4	1
Stictochironomus		1	
Tanytarsus	1	12	5
Tribelos		1	
EPHEMEROPTERA			
Apobaetis		8	
Caenis latipennis	508	233	40
Callibaetis	1		
Centroptilum	2	6	1
Leptophlebiidae	3		
Procloeon		1	1
Stenonema femoratum	3		

Tricorythodes	7	6	7
HEMIPTERA			
Rheumatobates			1
ODONATA			
Argia			15
Enallagma			22
Erythemis			3
Hetaerina			1
Macromia			3
Perithemis			2
TRICHOPTERA			
Hydroptila	1	1	
Nectopsyche		1	
Oecetis			1
Polycentropus			2
TRICLADIDA			
Planariidae	3	1	1
TUBIFICIDA			
Branchiura sowerbyi	5	7	
Tubificinae		9	
VENEROIDA			
Corbicula	5	9	
Pisidiidae			1

Macroinvertebrate Bench Sheet Report			
Oct 02, 2018 Little St. Francis River - [2854_13.0] - 18062			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina			2
AMPHIPODA			
Hyaella azteca			8
ARHYNCHOBDSELLIDA			
Erpobdellidae	*		
BASOMMATOPHORA			
Ancylidae	1	3	
COLEOPTERA			
Berosus	3	1	4
Dubiraphia		4	6
Optioservus sandersoni	8	7	
Psephenus herricki		1	
Scirtidae			4
Stenelmis	209	5	11
Tropisternus			1
DECAPODA			
Faxonius luteus	1	*	*
Faxonius punctimanus			*
Faxonius quadruncus	*		*
DIPTERA			
Ablabesmyia		10	1
Corynoneura	1		2
Cricotopus/Orthocladus	11		1
Dicrotendipes		2	
Eukiefferiella	1		
Glyptotendipes		1	
Hexatoma	*		
Paracladopelma		2	
Paraphaenocladus		1	
Polypedilum aviceps	2		
Polypedilum flavum	19	1	
Polypedilum illinoense grp	28	43	22
Polypedilum scalaenum grp	1	1	
Rheotanytarsus	3	2	2
Simulium	9		
Stempellinella		6	2
Tabanus	1		
Tanytarsus		6	6
Thienemanniella	3		1
Tribelos		9	

EPHEMEROPTERA			
Acerpenna			2
Baetis	14		
Caenis latipennis	16	114	154
Choroterpes		3	
Eurylophella bicolor		1	
Isonychia bicolor	1		
Stenacron		1	
Stenonema femoratum		4	2
Stenonema mediopunctatum	4		
Stenonema pulchellum	15		
Tricorythodes	110	8	22
LUMBRICINA			
Lumbricina	3	1	
MEGALOPTERA			
Corydalus	6		
ODONATA			
Argia		4	5
Basiaeschna janata			*
Enallagma			4
Gomphidae			*
Hagenius brevistylus		*	
Hetaerina			2
Macromia		1	*
PLECOPTERA			
Perlidae	2		
TRICHOPTERA			
Cheumatopsyche	62		5
Chimarra	13		5
Helicopsyche	8	2	18
Hydropsyche	1		
Nectopsyche			1
Oecetis		1	1
Oxyethira			1
Triaenodes			3
TRICLADIDA			
Planariidae	62	4	
TUBIFICIDA			
Branchiura sowerbyi		3	
Tubificinae		2	
VENEROIDA			
Corbicula	14	2	*
Pisidiidae	1	3	3

Macroinvertebrate Bench Sheet Report			
Sep 24, 2018 Little St. Francis River - [2854_10.4] - 18051			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina		3	1
AMPHIPODA			
Hyaella azteca			5
BASOMMATOPHORA			
Ancylidae	3		3
Menetus			1
Physella			1
COLEOPTERA			
Berosus		3	
Dubiraphia		5	4
Macronychus glabratus			17
Microcylloepus pusillus	4		22
Optioservus sandersoni	3		
Psephenus herricki	3		
Stenelmis	122	72	4
Tropisternus			*
DIPTERA			
Ablabesmyia		3	2
Cardiocladius	1		
Ceratopogoninae	1	2	
Chironomus		2	1
Cladopelma		3	
Cladotanytarsus	1	4	
Corynoneura		1	
Cricotopus bicinctus			1
Cricotopus/Orthocladius	6	1	1
Cryptochironomus		1	
Cryptotendipes		1	
Dicrotendipes	3	4	
Empididae (undescribed)		1	
Hexatoma	2		1
Labrundinia			2
Microtendipes			1
Nanocladius		1	
Paratanytarsus		1	5
Phaenopsectra		1	
Polypedilum flavum	17		15
Polypedilum halterale grp		5	
Polypedilum illinoense grp		1	4
Polypedilum scalaenum grp	1	1	
Procladius		1	

Psectrotanytus		1	
Pseudochironomus		2	
Rheotanytarsus	4	1	23
Simulium			1
Stempellinella		3	1
Stenochironomus			1
Stictochironomus		10	
Tanytarsus	1	19	25
Thienemannimyia grp		2	2
EPHEMEROPTERA			
Baetis	38		
Caenis anceps	8	45	6
Caenis latipennis	8	45	72
Centroptilum		1	
Choroterpes		1	
Eurylophella			1
Isonychia bicolor	3		
Stenonema femoratum		3	
Stenonema pulchellum	13		
Stenonema terminatum			4
Tricorythodes	187	9	61
LUMBRICINA			
Lumbricina	*	1	
MEGALOPTERA			
Corydalus	5		*
ODONATA			
Argia			9
Enallagma			9
Gomphidae		1	1
Hagenius brevistylus		1	*
Hetaerina			1
Macromia			*
PLECOPTERA			
Agnetina flavescens	5		
Neoperla	30	3	
TRICHOPTERA			
Cheumatopsyche	30		58
Chimarra	6		8
Glossosomatidae	5		
Helicopsyche	14	2	
Hydropsyche			1
Nectopsyche			2
Nectopsyche exquisita			3
Nectopsyche pavidia			1
Oecetis			4
Polycentropus			1
Trienodes			8

TRICLADIDA			
Planariidae	6	1	1
TUBIFICIDA			
Branchiura sowerbyi		2	
Tubificinae		5	
VENEROIDA			
Corbicula	63	4	*
Pisidiidae			1

Macroinvertebrate Bench Sheet Report			
Oct 02, 2018 Little St. Francis River - [2854_3.0] - 18064			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina	2	3	5
AMPHIPODA			
Hyaella azteca			4
BASOMMATOPHORA			
Ancylidae	1	4	3
Menetus			5
Physella		1	
COLEOPTERA			
Berosus			1
Dubiraphia		9	9
Helichus lithophilus			3
Macronychus glabratus			6
Microcylloepus pusillus	4	1	3
Psephenus herricki		1	
Stenelmis	257	13	14
DECAPODA			
Faxonius luteus	*	*	1
Faxonius punctimanus			*
DIPTERA			
Ablabesmyia		8	7
Ceratopogoninae		4	
Chironomus		10	
Cladopelma		2	
Cladotanytarsus	2	2	
Corynoneura		2	
Cricotopus bicinctus	1		
Cricotopus/Orthocladius	6	6	5
Cryptochironomus		3	
Dicrotendipes		5	
Eukiefferiella	5		
Forcipomyiinae			1
Hexatoma	4		
Labrundinia		1	4
Limnophila	1		
Nanocladius	5		
Paratanytarsus			3
Phaenopsectra		16	3
Polypedilum flavum	54	3	4
Polypedilum halterale grp		3	
Polypedilum illinoense grp	1	3	2
Polypedilum scalaenum grp		1	

Procladius		1	
Rheotanytarsus	15	5	6
Simulium	6		
Stempellina		1	
Stempellinella	1	7	6
Stenochironomus			2
Stictochironomus		6	
Tabanus	1		
Tanytarsus	2	55	38
Thienemanniella	4	2	2
Tipula	1		
Tribelos		14	4
EPHEMEROPTERA			
Apobaetis		1	
Baetis	2		1
Caenis anceps			2
Caenis latipennis	2	58	92
Centroptilum		3	1
Isonychia bicolor	11		
Leptophlebiidae		1	
Stenacron			3
Stenonema femoratum		1	
Stenonema pulchellum	38	1	5
Stenonema terminatum	5		
Tricorythodes	66	3	58
LUMBRICINA			
Lumbricina	*		
MEGALOPTERA			
Corydalus	4		
ODONATA			
Argia			2
Dromogomphus		*	
Enallagma			9
Gomphidae		1	
Hagenius brevistylus			*
Hetaerina			5
Macromia		*	*
PLECOPTERA			
Agnetina flavescens	12		
Neoperla	22	2	
TRICHOPTERA			
Cheumatopsyche	40		2
Chimarra	26		1
Helicopsyche	7	3	2
Hydropsyche	1	1	
Hydroptila		1	
Mystacides		1	

Nectopsyche		15	
Oecetis	2	3	14
Polycentropus		2	
Trienodes			1
TRICLADIDA			
Planariidae	4	1	1
TUBIFICIDA			
Branchiura sowerbyi		6	
Tubificinae		4	
VENEROIDA			
Corbicula	21	12	

Macroinvertebrate Bench Sheet Report			
Oct 02, 2018 Little St. Francis River - [2854_0.4] - 18065			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina	2	5	10
BASOMMATOPHORA			
Helisoma	1	1	
Physella			2
COLEOPTERA			
Ancyronyx variegatus			1
Dubiraphia	1	24	20
Ectopria nervosa	1		
Helichus lithophilus			2
Macronychus glabratus			16
Microcylloepus pusillus			14
Optioservus sandersoni	2		
Psephenus herricki	9		
Stenelmis	184	4	12
DIPTERA			
Ablabesmyia	2	9	10
Axarus			2
Ceratopogoninae	11	14	1
Chironomidae	2		
Chironomus		9	
Cladopelma		1	
Corynoneura		2	
Cricotopus/Orthocladius	6	2	
Cryptochironomus	4	6	
Cryptotendipes		1	
Demicryptochironomus		3	
Dicrotendipes		3	
Forcipomyiinae			1
Hexatoma	2		
Labrundinia	1	1	14
Nanocladius	1	1	3
Nilothauma		1	
Paracladopelma		1	
Parakiefferiella		3	
Paratanytarsus		1	
Phaenopsectra		9	4
Polypedilum flavum	12		2
Polypedilum halterale grp		21	2
Polypedilum illinoense grp		2	7
Polypedilum scalaenum grp	3		
Procladius		1	

Pseudochironomus		12	
Rheotanytarsus		6	16
Robackia	2		
Stempellinella	10	23	4
Stictochironomus	1	15	
Tanytarsus	19	62	38
Thienemanniella	2	4	2
Thienemannimyia grp			1
EPHEMEROPTERA			
Apobaetis	5	6	
Baetis	18		1
Caenis latipennis	8	17	25
Choroterpes		1	
Hexagenia limbata		3	
Isonychia bicolor	4		
Leptophlebiidae	1	1	
Sparbarus		1	
Stenacron		1	
Stenonema femoratum	2	3	
Stenonema pulchellum	16	1	5
Stenonema terminatum	1	1	3
Tricorythodes	38	1	11
LUMBRICINA			
Lumbricina	1		
MEGALOPTERA			
Sialis		*	
ODONATA			
Argia			6
Enallagma			10
Gomphidae		1	
Gomphus			4
Hetaerina			2
Macromia		*	2
Progomphus obscurus		1	1
PLECOPTERA			
Isoperla	47	1	
TRICHOPTERA			
Agapetus	107	1	
Cheumatopsyche	6		1
Chimarra	2		
Helicopsyche	40		3
Hydropsyche	1		
Leptoceridae			4
Mystacides	1	1	
Nectopsyche		3	2
Oecetis	2	2	7
Polycentropus		2	2

Trienodes			3
TRICLADIDA			
Planariidae			1
TUBIFICIDA			
Branchiura sowerbyi		1	1
Tubificinae	1	1	
VENEROIDA			
Corbicula	19		
Pisidiidae		1	1

Macroinvertebrate Bench Sheet Report			
Sep 26, 2018 Village Creek - [2864_0.2] - 18057			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina	1	13	3
AMPHIPODA			
Hyaella azteca		4	65
ARHYNCHOBDELLIDA			
Erpobdellidae	*		
BASOMMATOPHORA			
Ancylidae	5		2
Helisoma	1	*	8
Lymnaeidae	1		
Menetus	1	2	1
Physella		*	3
COLEOPTERA			
Berosus			2
Dubiraphia		10	4
Microcylloepus pusillus	4		4
Optioservus sandersoni	2		
Psephenus herricki	69		
Stenelmis	95		18
DECAPODA			
Faxonius luteus			1
Faxonius punctimanus			1
Faxonius quadruncus	1		1
DIPTERA			
Ablabesmyia		12	5
Ceratopogoninae		2	
Chironomidae		2	
Chironomus		10	
Cladopelma		5	1
Cladotanytarsus		1	
Clinotanypus		2	
Corynoneura		1	1
Cricotopus/Orthocladius	3		1
Cryptochironomus		12	
Einfeldia		4	
Endotribelos			2
Forcipomyiinae	1		
Hexatoma	*		
Labrundinia		1	1
Larsia			2
Nanocladius		1	
Parakiefferiella		2	

Paratanytarsus		1	3
Paratendipes			1
Polypedilum flavum	43		
Polypedilum illinoense grp	12	3	35
Polypedilum scalaenum grp	16	1	1
Polypedilum trigonum			4
Procladius		1	
Pseudochironomus		2	
Rheotanytarsus	25	1	6
Stempellinella	10	5	
Stictochironomus		4	
Tanypus	1		
Tanytarsus	58	72	11
Thienemanniella	4	1	2
Thienemannimyia grp	6	1	
Zavreliella		2	
EPHEMEROPTERA			
Acerpenna	4		
Baetis	32		
Caenis latipennis	98	98	10
Callibaetis			1
Isonychia bicolor	3		
Leptophlebiidae			1
Proclaeon		2	1
Stenacron	33		
Stenonema femoratum	2	3	
Stenonema pulchellum	6		
Stenonema terminatum	12		
Tricorythodes	48		1
HEMIPTERA			
Belostoma			*
LEPIDOPTERA			
Parapoynx	*		1
MEGALOPTERA			
Corydalus	*		
ODONATA			
Argia	9		13
Basiaeschna janata			1
Enallagma		2	41
Erythemis			7
Hetaerina	14		1
Ischnura			5
Libellula	*		4
PLECOPTERA			
Acroneuria	*		
Paragnetina	2		

RHYNCHOBDELLIDA			
Glossiphoniidae		1	
TRICHOPTERA			
Cheumatopsyche	25		1
Chimarra	1		
Helicopsyche	7		
Hydropsyche	1		
Hydroptila			1
Oecetis		1	
TRICLADIDA			
Planariidae			7
TUBIFICIDA			
Aulodrilus	6	2	
Branchiura sowerbyi	2	1	2
Tubificinae	8	4	
VENEROIDA			
Corbicula			*
Pisidiidae	1	5	4

Macroinvertebrate Bench Sheet Report			
Sep 26, 2018 Village Creek - [2863_1.7] - 18056			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina	1	6	9
AMPHIPODA			
Hyalella azteca		4	2
BASOMMATOPHORA			
Ancylidae	11	2	2
Helisoma			1
Lymnaeidae	1		
Menetus			16
Physella			2
COLEOPTERA			
Ancyronyx variegatus		1	
Dubiraphia		10	64
Ectopria nervosa		1	
Macronychus glabratus	4		4
Microcylloepus pusillus	3		
Optioservus sandersoni			1
Psephenus herricki	7		
Stenelmis	80	8	18
DECAPODA			
Faxonius luteus	*	*	
DIPTERA			
Ablabesmyia		16	4
Ceratopogoninae		6	
Chironomidae	1	4	1
Chironomus	1	32	
Chrysops			1
Cladopelma		9	
Cladotanytarsus		2	
Clinotanytus		1	7
Corynoneura	8	1	
Cricotopus bicinctus	3		
Cricotopus/Orthocladius	1	1	
Cryptochironomus	4	5	
Cryptotendipes		5	
Dicrotendipes		2	
Hemerodromia	4		
Hexatoma	*		
Labrundinia		1	15
Microtendipes		1	
Nanocladius			2
Nilothauma		1	

Parakiefferiella		1	
Paraphaenocladus		1	
Paratanytarsus	1	1	6
Paratendipes		9	2
Polypedilum fallax grp	1		
Polypedilum flavum	123	2	
Polypedilum halterale grp		7	6
Polypedilum illinoense grp	87	3	3
Polypedilum scalaenum grp	4	7	
Procladius		2	2
Pseudochironomus	1	4	
Rheotanytarsus	68	1	
Simulium	2		
Stempellinella	12	15	2
Tabanus	*		
Tanytarsus	91	177	47
Thienemanniella	7	1	
Thienemannimyia grp	15	1	1
Tipula	5	1	
Tribelos		1	11
EPHEMEROPTERA			
Acerpenna	1		
Apobaetis		3	
Baetis	1		
Caenis latipennis	23	20	11
Centropilum		1	1
Choroterpes		1	
Ephemera simulans		1	
Eurylophella		1	
Isonychia bicolor	1		
Leptophlebiidae		1	13
Proclaeon		1	
Stenacron	9	4	2
Stenonema femoratum	1	5	
Stenonema pulchellum	10	1	
Stenonema terminatum	5		
Tricorythodes	14	1	
ISOPODA			
Caecidotea	4		1
Caecidotea (Blind & Unpigmented)		1	
LEPIDOPTERA			
Crambidae	*		
MEGALOPTERA			
Corydalus	*		
Sialis		*	
ODONATA			

Argia	*	1	8
Dromogomphus			*
Enallagma			24
Gomphidae	1	2	2
Libellula			2
Macromia			1
Stylogomphus albistylus	1		
PLECOPTERA			
Acroneuria	*		
TRICHOPTERA			
Cheumatopsyche	57		
Chimarra	10		
Oecetis	1	2	2
Triaenodes			6
Wormaldia	2		
TRICLADIDA			
Planariidae		1	9
TUBIFICIDA			
Branchiura sowerbyi	3	5	2
Tubificinae	8	27	3
VENEROIDA			
Corbicula	9	24	2
Pisidiidae	5	6	8

Macroinvertebrate Bench Sheet Report			
Sep 25, 2018 Saline Creek - [2859_3.2] - 18052			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina		1	4
AMPHIPODA			
Gammarus	1		14
Hyaella azteca		11	95
BASOMMATOPHORA			
Ancylidae	3	17	1
Lymnaeidae			2
Menetus			10
Physella	*	1	4
COLEOPTERA			
Dubiraphia		6	8
Ectopria nervosa	2		
Helichus basalis			1
Hydrophilidae			1
Macronychus glabratus			4
Optioservus sandersoni	4		
Psephenus herricki	110	1	1
Scirtidae			2
Stenelmis	71	1	25
DECAPODA			
Faxonius luteus	*		1
Faxonius punctimanus	1		1
DIPTERA			
Ablabesmyia	4	4	2
Ceratopogoninae	1	3	2
Chironomidae		2	2
Chironomus	1	13	1
Chrysops	1		
Cladotanytarsus		19	4
Clinotanytus			1
Corynoneura			3
Cryptochironomus	1	1	
Dicrotendipes		2	1
Dixella			3
Endochironomus		6	2
Ephydriidae		1	1
Forcipomyiinae	3	10	2
Glyptotendipes		1	
Hexatoma	3		
Labrundinia			8
Limnophyes			3

Microtendipes	10	1	5
Nanocladius			1
Parachironomus			1
Paralauterborniella	1		1
Paraphaenocladius			3
Paratanytarsus		4	12
Paratendipes		5	
Polypedilum flavum	14	2	3
Polypedilum illinoense grp	4	13	11
Polypedilum scalaenum grp	1		1
Polypedilum trigonum		1	3
Procladius		2	
Pseudochironomus		2	1
Rheotanytarsus	10	2	2
Simulium	1	1	
Stempellinella	8	3	6
Stenochironomus	1	1	
Stictochironomus		1	
Tabanus	*		
Tanytarsus	9	28	21
Thienemanniella		1	
Thienemannimyia grp	6		4
Tribelos	2		
EPHEMEROPTERA			
Acerpenna	7		
Baetis	5		
Caenis anceps	94	1	6
Caenis latipennis	46	57	11
Ephemera simulans	3		
Isonychia bicolor	30		1
Leptophlebiidae	1		8
Plautitus	1		
Stenacron	14	4	1
Stenonema femoratum	7	30	
Stenonema pulchellum	42		
Stenonema terminatum	13		
GORDIOIDEA			
Chordodidae	*		
HEMIPTERA			
Veliidae	1		
LUMBRICINA			
Lumbricina	*		
MEGALOPTERA			
Corydalus	2		*
Nigronia serricornis	2		
Sialis	*	1	
ODONATA			

Argia	15	1	1
Calopteryx			4
Enallagma		2	17
Gomphidae	14		
Hetaerina		1	10
Ischnura		1	
Stylogomphus albistylus	1		
PLECOPTERA			
Acroneuria	3		
TRICHOPTERA			
Cheumatopsyche	25		1
Chimarra	38	1	
Helicopsyche	1		
Hydropsyche	1		
Polycentropus	1		
Triaenodes			2
TRICLADIDA			
Planariidae	1		1
TUBIFICIDA			
Branchiura sowerbyi	8	13	1
Tubificinae	3	1	
VENEROIDA			
Corbicula	1	4	1

Macroinvertebrate Bench Sheet Report			
Sep 25, 2018 Saline Creek - [2859_2.0] - 18055			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina	1	9	1
AMPHIPODA			
Crangonyx			*
Hyaella azteca		1	56
BASOMMATOPHORA			
Ancylidae	13		
Helisoma	1		
Menetus	9	1	12
Physella	1		4
COLEOPTERA			
Dubiraphia	10	18	19
Ectopria nervosa	1		
Helichus fastigiatus			1
Macronychus glabratus	4		3
Psephenus herricki	48		
Stenelmis	98	2	31
DECAPODA			
Faxonius luteus	1		
DIPTERA			
Ablabesmyia	3	2	2
Ceratopogoninae	1	3	1
Chironomidae	3	4	1
Chironomus	2	89	5
Cladopelma		11	
Cladotanytarsus	1	4	
Clinotanytus		1	
Corynoneura		1	4
Cricotopus/Orthocladius	4		5
Cryptochironomus	4		
Cryptotendipes	1	6	
Dicrotendipes		2	5
Dixella			1
Forcipomyiinae			1
Hemerodromia			2
Hexatoma	1		
Microtendipes	1		
Muscidae	1		
Myxosargus			1
Nanocladius			1
Paratanytarsus	5	1	19
Phaenopsectra	3	12	7

Polypedilum flavum	23		1
Polypedilum halterale grp	1	1	
Polypedilum illinoense grp	16		26
Polypedilum scalaenum grp	2		
Polypedilum trigonum			1
Pseudochironomus	2	5	2
Rheotanytarsus	4		5
Simulium	1		
Stempellinella	21	13	1
Stenochironomus	1	2	1
Stictochironomus		1	
Tanytus		2	
Tanytarsus	25	46	30
Thienemanniella	1		
Thienemannimyia grp	2		4
Tipula	1		
Tribelos	2		
Zavrelimyia			4
EPHEMEROPTERA			
Acerpenna	4		
Baetis	2		
Caenis anceps	35		2
Caenis latipennis	68	6	5
Centropilum		2	1
Ephemera simulans	1		
Isonychia bicolor	2		
Leptophlebiidae	6		
Stenacron	6		
Stenonema femoratum	14	1	
Stenonema pulchellum	3		1
Tricorythodes	30		3
HEMIPTERA			
Veliidae		1	
ISOPODA			
Caecidotea (Blind & Unpigmented)		1	1
LUMBRICINA			
Lumbricina	6	3	
MEGALOPTERA			
Nigronia serricornis	1		
NEOTAENIOGLOSSA			
Hydrobiidae			1
ODONATA			
Argia	12		3
Calopteryx			2
Enallagma	1		29
Gomphidae	1	1	

Stylogomphus albistylus	1		
PLECOPTERA			
Acroneuria	1		
Perlidae	4		
TRICHOPTERA			
Cheumatopsyche	10		2
Chimarra	4		
Helicopsyche	3		
Hydroptila	1		2
Oecetis		2	4
Triaenodes			1
TRICLADIDA			
Planariidae	1		2
TUBIFICIDA			
Branchiura sowerbyi	1	7	
Limnodrilus hoffmeisteri	1		
Tubificinae	2	12	1
VENEROIDA			
Corbicula	41		
Pisidiidae	1	2	

Macroinvertebrate Bench Sheet Report			
Sep 25, 2018 Saline Creek - [2859_1.3] - 18053			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina	14	14	3
BASOMMATOPHORA			
Physella	70	13	58
COLEOPTERA			
Dubiraphia			2
Helichus basalis			3
Neoporus			1
Stenelmis	2		3
DIPTERA			
Ablabesmyia	5	17	6
Ceratopogoninae		3	4
Chironomidae	2	2	3
Chironomus		22	1
Chrysops	*		
Cladopelma		39	1
Corynoneura	5		6
Cricotopus bicinctus	9	1	
Cricotopus/Orthocladius	39	13	1
Dicrotendipes	1	7	1
Empididae	1		
Eukiefferiella	1		
Forcipomyiinae	2		
Hemerodromia	13		
Labrundinia			4
Nanocladius	2	1	1
Parakiefferiella	1	3	
Parametriocnemus	1		
Paraphaenocladius			2
Phaenopsectra	1	6	3
Polypedilum fallax grp	1		
Polypedilum flavum	7		
Polypedilum halterale grp		8	22
Polypedilum illinoense grp	76	14	18
Polypedilum scalaenum grp	4	8	2
Procladius		6	
Psectrocladius	1	3	
Pseudochironomus	2	1	
Rheotanytarsus	18		3
Simulium	7		
Smittia			1
Stempellinella		1	
Tanytarsus	27	101	4

Thienemanniella	4		1
Thienemannimyia grp	1		
Tribelos	1	31	20
EPHEMEROPTERA			
Caenis latipennis			2
HEMIPTERA			
Veliidae		1	
MEGALOPTERA			
Corydalus	*		
ODONATA			
Argia	17		6
Boyeria	1		
Calopteryx	2		
Enallagma			1
Gomphidae			1
Libellulidae			1
Stylogomphus albistylus	1		
TRICHOPTERA			
Cheumatopsyche	244		1
Chimarra	13		
Hydroptila	4	1	
Oecetis	2		1
Polycentropus	3	6	4
Triaenodes			1
TUBIFICIDA			
Tubificinae			2
VENEROIDA			
Pisidiidae	4		72

Macroinvertebrate Bench Sheet Report			
Sep 25, 2018 Saline Creek - [2859_1.2] - 18054			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina	8	8	
AMPHIPODA			
Crangonyx			1
BASOMMATOPHORA			
Lymnaeidae			3
Physella	46	4	137
COLEOPTERA			
Dubiraphia		1	
Ectopria nervosa	1		
Haliplidae	4	1	1
Helichus lithophilus	1		1
Optioservus sandersoni			1
Stenelmis	1	2	
DIPTERA			
Ablabesmyia	2	16	4
Ceratopogoninae			1
Chironomidae		1	
Chironomus	15	93	1
Cladopelma	5	22	
Cladotanytarsus		1	
Corynoneura	1	1	
Cricotopus bicinctus	3		
Cricotopus/Orthocladius	4	1	
Dicortendipes	3	13	
Forcipomyiinae	1	4	45
Hemerodromia	1		
Labrundinia			3
Larsia	1	1	
Limonia			3
Micropsectra	1		
Myxosargus		1	
Nanocladius	1		2
Natarsia		1	
Parakiefferiella	2		
Paraphaenocladius	1		3
Phaenopsectra			1
Polypedilum flavum	1		
Polypedilum halterale grp	2	60	
Polypedilum illinoense grp	8	5	7
Polypedilum scalaenum grp	1	3	
Procladius	4	4	

Rheotanytarsus	5	1	
Stictochironomus		2	
Tanypus		1	
Tanytarsus	11	30	1
Thienemannimyia grp			1
Tipula			1
Tribelos	5	18	1
EPHEMEROPTERA			
Stenonema femoratum		1	
HEMIPTERA			
Microvelia	1		
ISOPODA			
Lirceus			2
LUMBRICINA			
Lumbricina			2
LUMBRICULIDA			
Lumbriculidae			1
ODONATA			
Argia	21	1	17
Corduliidae	1	1	
Enallagma			9
Hagenius brevistylus	1		
Hetaerina	1		
Libellulidae			1
Stylogomphus albistylus	2		
TRICHOPTERA			
Cheumatopsyche	14		
Hydroptila	6		
Oecetis	2		1
Polycentropus	2		
TRICLADIDA			
Planariidae			2
TUBIFICIDA			
Aulodrilus		1	
Enchytraeidae			1
Limnodrilus udekemianus		1	
Tubificinae	4	11	
VENEROIDA			
Pisidiidae	3	3	56

Macroinvertebrate Bench Sheet Report			
Mar 18, 2019 Village Creek - [2864_0.2] - 19028			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina	7	1	7
AMPHIPODA			
Crangonyx	2		
Hyaella azteca	1	2	42
ARHYNCHOBDELLIDA			
Erpobdellidae	1	*	*
BASOMMATOPHORA			
Ancylidae	4		
Gyraulid	8	2	
Helisoma	1		1
Lymnaeidae	2		
Physella	4	9	
COLEOPTERA			
Berosus	4	1	
Dubiraphia	5	2	1
Ectopria nervosa	1		
Macronychus glabratus			1
Microcylloepus pusillus	16	8	
Neoporus			1
Peltodytes			4
Psephenus herricki	3		
Stenelmis	39	14	29
DECAPODA			
Faxonius luteus	1	*	
Faxonius punctimanus			*
DIPTERA			
Ablabesmyia	2		2
Ceratopogoninae	2	1	
Chironomus	3	1	1
Cladotanytarsus	1		1
Clinocera	2	2	
Clinotanytus	1		
Corynoneura	3		4
Cricotopus/Orthocladius	41	18	31
Cryptochironomus	5	2	
Diamesa		1	
Dicrotendipes		1	
Diplocladius	1		
Eukiefferiella	111	54	32
Hemerodromia			2
Hydrobaenus	3	1	1

Nanocladius			1
Nilothauma	2		
Parametriocnemus	3	1	
Paratanytarsus	5	1	32
Paratendipes	2		
Phaenopsectra	5	1	1
Polypedilum aviceps	2	3	
Polypedilum flavum	8	1	1
Polypedilum illinoense grp	1	2	1
Polypedilum scalaenum grp	4	5	
Prosimulium	8	2	
Pseudochironomus	3		
Pseudosmittia			1
Rheocricotopus	1		
Rheotanytarsus	101	31	50
Simulium	5	2	1
Stempellinella	25	13	7
Stenochironomus			1
Stictochironomus	6	3	
Tanytarsus	37	17	21
Thienemanniella	1		2
Thienemannimyia grp	11	3	4
Tipula	*		
Tribelos	1	1	
Zavrelimyia	1		
EPHEMEROPTERA			
Acentrella		2	
Acerpenna	3		1
Caenis latipennis	74	62	44
Choroterpes			*
Ephemera simulans		*	
Fallceon	1		
Isonychia bicolor		1	
Plauditus	4	1	2
Stenacron	6	3	
Stenonema femoratum	6	4	*
Stenonema pulchellum	7	7	1
Stenonema terminatum	1	3	
Tricorythodes		1	
ISOPODA			
Caecidotea	1		
LEPIDOPTERA			
Petrophila	2		
ODONATA			
Argia	2		5
Basiaeschna janata			*
Enallagma	1		16

Erythemis	1		*
Hagenius brevistylus			*
Hetaerina	1	1	
Ischnura			3
PLECOPTERA			
Acroneuria	*	*	
Leuctridae	1		
Neoperla		1	
Perlesta	4	3	
TRICHOPTERA			
Cheumatopsyche	8	7	2
Chimarra	1	1	
Dibusa angata	41	21	21
Helicopsyche	3		
Hydropsyche	*		
Hydroptila	7		1
Ochrotrichia	22	12	5
Pycnopsyche	*		*
Triaenodes			1
TRICLADIDA			
Planariidae	3	2	
TUBIFICIDA			
Branchiura sowerbyi	9		
Limnodrilus hoffmeisteri	4	1	
Tubificinae	18	5	
VENEROIDA			
Corbicula	9	2	

Macroinvertebrate Bench Sheet Report			
Mar 18, 2019 Village Creek - [2863_1.7A] - 19026			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina		5	
AMPHIPODA			
Crangonyx	3	3	8
Hyaella azteca			9
BASOMMATOPHORA			
Ancylidae	2	2	2
Gyraulid	1		4
Helisoma		1	
Physella		5	3
COLEOPTERA			
Berosus		2	
Dubiraphia		4	4
Helichus basalis			1
Helichus lithophilus			1
Microcylloepus pusillus	7		4
Neoporus		1	
Peltodytes			1
Psephenus herricki	4		
Stenelmis	88	6	13
DECAPODA			
Faxonius luteus	*		*
Faxonius quadruncus		*	
Faxonius virilis		*	
DIPTERA			
Ablabesmyia		4	
Ceratopogoninae		14	
Chironomidae		5	1
Chironomus		32	
Cladotanytarsus		3	
Clinocera	8	1	
Corynoneura	1	2	11
Cricotopus/Orthocladius	54	12	17
Cryptochironomus	2	4	1
Cryptotendipes		2	
Dicortendipes		1	
Diplocladius			1
Einfeldia		1	
Eukiefferiella	91	7	7
Hemerodromia	9	1	1
Hexatoma	1		
Hydrobaenus		9	

Limnophila		1	
Limnophyes		1	
Micropsectra			2
Microtendipes		1	
Nanocladius			1
Natarsia		4	
Orthocladius (Euorthocladius)	1		
Parachaetocladius	1		
Parametriocnemus	2		
Paratanytarsus			40
Paratendipes		11	
Phaenopsectra		9	
Polypedilum aviceps	1		
Polypedilum flavum	9		2
Polypedilum halterale grp		12	
Polypedilum scalaenum grp	23	15	
Prosimulium	6		
Rheocricotopus	2		2
Rheotanytarsus	55	3	30
Simulium	1		4
Stempellinella	13	49	11
Stictochironomus		13	
Tabanus	*		
Tanytarsus	62	32	23
Thienemanniella			3
Thienemannimyia grp	22	1	8
Tipula	*		
Zavrelimyia		1	1
EPHEMEROPTERA			
Acerpenna	4		1
Caenis anceps	1		
Caenis latipennis	25	14	30
Centroptilum			2
Dipheter	3		
Isonychia bicolor	*		1
Leptophlebiidae		1	
Plauditus	2		1
Stenacron	6	3	1
Stenonema femoratum	2	3	1
Stenonema mediopunctatum			1
Stenonema pulchellum	6	1	4
Stenonema terminatum	4		1
Tricorythodes	1		
ISOPODA			
Caecidotea	2	2	3
LUMBRICINA			

Lumbricina		1	
MEGALOPTERA			
Sialis		*	
NEOTAENIOGLOSSA			
Hydrobiidae			2
ODONATA			
Argia		2	6
Boyeria			*
Didymops		1	
Enallagma			10
Erythemis			*
PLECOPTERA			
Acroneuria	*		
Amphinemura	1		1
Perlidae	1		3
TRICHOPTERA			
Cheumatopsyche	26		2
Chimarra	7		2
Dibusa angata	35		7
Hydroptila	1		
Ochrotrichia	24	1	3
Oecetis			1
Pycnopsyche	*		*
Triaenodes			3
TRICLADIDA			
Planariidae	3		2
TUBIFICIDA			
Enchytraeidae		3	
Limnodrilus hoffmeisteri	1	2	
Tubificinae	6	13	
VENEROIDA			
Corbicula	1	3	

Macroinvertebrate Bench Sheet Report			
Mar 18, 2019 Village Creek - [2863_1.7B] - 19027			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina	3	1	
AMPHIPODA			
Crangonyx	2	5	2
Hyaella azteca		1	9
Stygobromus		1	
BASOMMATOPHORA			
Ancylidae		1	
Gyraulid			1
Physella		2	1
COLEOPTERA			
Ancyronyx variegatus			2
Berosus	1		
Dubiraphia	1	1	4
Ectopria nervosa			*
Macronychus glabratus	1		
Microcylloepus pusillus	7		9
Neoporus			1
Peltodytes			1
Psephenus herricki	6	1	
Stenelmis	83	6	25
DECAPODA			
Faxonius luteus	*		1
Faxonius quadruncus	*		
DIPTERA			
Ablabesmyia		6	2
Ceratopogoninae		8	
Chironomidae	3	2	2
Chironomus		27	
Cladotanytarsus		5	
Clinocera	9	1	
Clinotanytus		1	1
Corynoneura	1	1	6
Cricotopus bicinctus	1		3
Cricotopus/Orthocladius	71	13	17
Cryptochironomus		17	
Diamesa		1	
Dicrotendipes		3	
Diplocladius		1	
Eukiefferiella	98	14	13
Glyptotendipes		1	
Gonomyia			1

Hemerodromia	8		
Hexatoma	2		
Hydrobaenus		11	
Larsia			1
Limnophyes	1		
Micropsectra	3		1
Microtendipes		1	1
Nanocladius		1	
Orthocladius (Euorthocladius)	2		
Parametriocnemus			1
Paraphaenocladius	1		
Paratanytarsus	7	2	19
Paratendipes		7	1
Pericomaina		1	
Phaenopsectra		4	
Pilaria			1
Polypedilum aviceps	4	2	2
Polypedilum fallax grp			1
Polypedilum flavum	9		2
Polypedilum halterale grp	1	6	1
Polypedilum scalaenum grp	17	9	
Prosimulium	1		
Rheocricotopus	3		1
Rheotanytarsus	67	24	53
Simulium	7		5
Stempellinella	17	31	29
Stictochironomus		16	
Tabanus	*	*	
Tanytarsus	63	32	41
Thienemanniella	3		2
Thienemannimyia grp	9	3	36
Tipula	*		*
Tribelos		6	1
Tvetenia bavarica grp	2		1
Zavreliomyia		2	
Zavreliomyia (Paramerina)			1
EPHEMEROPTERA			
Acerpenna	1		1
Caenis latipennis	28	10	32
Ephemera simulans		*	
Eurylophella enoensis		1	
Isonychia bicolor			1
Leptophlebiidae			1
Plautidius	5		3
Stenacron	12	2	
Stenonema femoratum	5	1	*
Stenonema pulchellum	12		*

Tricorythodes	2		
ISOPODA			
Caecidotea	2	2	11
MEGALOPTERA			
Corydalus	*		
ODONATA			
Argia	2	1	3
Dromogomphus			1
Enallagma			4
Ischnura			1
Libellula		*	*
PLECOPTERA			
Acroneuria	*		
Amphinemura	1		
Isoperla	1		
Perlesta	1		3
TRICHOPTERA			
Agapetus	1		
Cheumatopsyche	17		2
Chimarra	3		
Dibusa angata	111		2
Helicopsyche	1		
Hydroptila	2	1	
Micrasema	1		
Ochrotrichia	67	1	4
Pycnopsyche			*
Rhyacophila	1		
Triaenodes			2
TRICLADIDA			
Planariidae	3		2
TUBIFICIDA			
Branchiura sowerbyi		6	*
Limnodrilus hoffmeisteri	2	1	
Tubificinae	2	13	1
VENEROIDA			
Corbicula	3	4	1

Macroinvertebrate Bench Sheet Report			
Mar 19, 2019 Saline Creek - [2859_3.2] - 19030			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina	7	20	1
AMPHIPODA			
Crangonyx		1	3
Gammarus			*
Hyaella azteca			5
Stygobromus		1	
BASOMMATOPHORA			
Ancylidae	3		
COLEOPTERA			
Dubiraphia		7	2
Ectopria nervosa	1		
Microcylloepus pusillus	15		1
Optioservus sandersoni	6		
Peltodytes	1		
Psephenus herricki	4	8	1
Scirtidae			2
Stenelmis	66	1	3
DECAPODA			
Faxonius luteus	*	*	*
Faxonius punctimanus	*		
Faxonius quadruncus			*
Faxonius virilis		*	*
DIPTERA			
Ablabesmyia		2	
Ceratopogoninae		12	4
Chironomidae		6	2
Chironomus		1	2
Chrysops	1		
Cladotanytarsus		12	2
Clinocera	28	1	2
Constempellina	1		
Corynoneura		5	8
Cricotopus/Orthocladius	138	10	68
Cryptochironomus		1	
Cryptotendipes		1	
Dicrotendipes		2	
Eukiefferiella	137	2	16
Forcipomyiinae			1
Gonomyia		1	
Hemerodromia	11		1
Hexatoma	*		

Hydrobaenus		5	3
Micropsectra			1
Microtendipes		5	1
Natarsia		4	
Nemotelus		1	
Orthocladius (Euorthocladius)	2		
Parachaetocladius	1		
Paralauterborniella		1	
Parametriocnemus	1		
Paraphaenocladius			1
Paratanytarsus	1	2	7
Paratendipes		25	3
Pericomaina			1
Phaenopsectra		9	1
Polypedilum aviceps	3		
Polypedilum flavum	6		2
Polypedilum halterale grp		6	
Polypedilum illinoense grp		2	3
Polypedilum scalaenum grp		13	1
Prosimulium	3		1
Pseudochironomus	1		
Rheocricotopus	12		2
Rheotanytarsus	16	2	14
Simulium	25		4
Stempellinella	12	6	18
Stictochironomus		22	2
Sympothastia			1
Tanytarsus	15	20	20
Thienemanniella		1	3
Thienemannimyia grp	3	3	14
Tipula	*		*
Tribelos		11	
Xenochironomus	1		
Zavrelimyia		2	1
EPHEMEROPTERA			
Acerpenna	3		
Caenis latipennis	20	34	58
Centropilum		1	1
Dipheter			1
Ephemera simulans		2	
Eurylophella	1		
Heterocloeon	1		
Isonychia bicolor	2		1
Leptophlebia			1
Plauditus	3		2
Stenacron	3	3	1
Stenonema femoratum	1	9	1

Stenonema pulchellum	14		4
GORDIOIDEA			
Gordiidae	*		
HEMIPTERA			
Belostoma			*
Notonecta		1	
ISOPODA			
Caecidotea (Blind & Unpigmented)			1
MEGALOPTERA			
Corydalus	*		
Nigronia serricornis			*
ODONATA			
Argia		2	1
Calopteryx			1
Dromogomphus			1
Enallagma			4
Gomphidae	2		
Hagenius brevistylus		*	
PLECOPTERA			
Acroneuria	*		
Alloperla	1		
Clioperla clio			*
Isoperla	1		
Perlesta	7		3
TRICHOPTERA			
Cheumatopsyche	18	2	1
Chimarra	20		2
Dibusa angata	36		4
Helicopsyche	3		
Hydroptila	3		2
Pycnopsyche	*		*
Rhyacophila	2		
TRICLADIDA			
Planariidae	6	1	
TUBIFICIDA			
Branchiura sowerbyi		9	
Limnodrilus hoffmeisteri		3	
Tubificinae	2	10	2
VENEROIDA			
Corbicula	5		
Pisidiidae	1		2

Macroinvertebrate Bench Sheet Report			
Mar 19, 2019 Saline Creek [2859_2.0] - 19031			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina	5		2
AMPHIPODA			
Crangonyx	5	2	7
Gammarus			2
Hyaella azteca		1	16
BASOMMATOPHORA			
Ancylidae	9		
Menetus	3		
Physella	5		1
COLEOPTERA			
Berosus	1		
Dubiraphia	4	9	3
Ectopria nervosa	1		
Macronychus glabratus	1		1
Microcylloepus pusillus	5	2	
Neoporus			1
Optioservus sandersoni	6		
Paracymus	1	3	
Peltodytes		1	
Psephenus herricki	22	1	1
Stenelmis	40	1	4
DECAPODA			
Faxonius luteus	*		
Faxonius punctimanus		1	*
Faxonius quadruncus	*		
DIPTERA			
Ablabesmyia	2	1	
Ceratopogoninae	1	16	1
Chironomidae	2	4	2
Chironomus	3	25	
Chrysops		1	
Cladotanytarsus		4	
Clinocera	50	2	
Corynoneura	3	1	4
Cricotopus/Orthocladius	97	3	70
Cryptochironomus		1	1
Dicrotendipes		8	
Eukiefferiella	67	2	14
Glyptotendipes			1
Hemerodromia	12		4
Hexatoma	*		

Hydrobaenus		1	
Limonia			2
Microtendipes		2	1
Myxosargus	1		
Nanocladius			1
Natarsia		2	
Nemotelus		1	
Paracladopelma		1	
Parametriocnemus			1
Paratanytarsus	4	1	26
Paratendipes		34	2
Phaenopsectra		2	
Polypedilum aviceps	8		
Polypedilum flavum	2		2
Polypedilum halterale grp		6	
Polypedilum illinoense grp		1	
Polypedilum scalaenum grp	1	14	
Potthastia			1
Procladius		1	
Prosimulium	3		1
Pseudochironomus	1	2	
Rheocricotopus	6		3
Rheotanytarsus	6		13
Simulium	13		7
Smittia	2	1	4
Stempellinella	19	22	13
Stictochironomus		11	
Sympotthastia	1		1
Tabanus	1		
Tanytarsus	20	13	18
Thienemanniella			1
Thienemannimyia grp	10		13
Tipula	5		*
Tribelos	7	34	8
Tvetenia bavarica grp	2		
Zavrelimyia		4	
EPHEMEROPTERA			
Acentrella	4		
Acerpenna	16		4
Baetis	1		
Caenis latipennis	63	16	53
Centroptilum		2	4
Ephemera simulans		1	
Eurylophella bicolor	3		
Eurylophella enoensis			3
Isonychia bicolor	10		1
Stenacron	5		1

Stenonema femoratum	7	1	1
Stenonema pulchellum	22		1
Tricorythodes	3		1
ISOPODA			
Caecidotea	14		8
Caecidotea (Blind & Unpigmented)	2		
LUMBRICINA			
Lumbricina	13	4	1
LUMBRICULIDA			
Lumbriculidae		1	
MEGALOPTERA			
Corydalus	*		
Nigronia serricornis			1
ODONATA			
Argia		1	2
Calopteryx			2
Dromogomphus			1
Enallagma			5
Hagenius brevistylus		*	1
Libellula			*
Macromia			1
Stylogomphus albistylus	5	1	
PLECOPTERA			
Acroneuria	1		
Leuctridae	1		
Perlesta	8		
TRICHOPTERA			
Cheumatopsyche	29		5
Chimarra	19		2
Dibusa angata	9		2
Helicopsyche	2		2
Hydroptila			3
Ochrotrichia	4		3
Oecetis			3
Polycentropus			2
Ptilostomis			*
Pycnopsyche	*		1
Rhyacophila	2		
Triaenodes			1
TRICLADIDA			
Planariidae	12		4
TUBIFICIDA			
Branchiura sowerbyi		2	1
Enchytraeidae	1		
Limnodrilus clapedianus			2
Limnodrilus hoffmeisteri	3		2

Limnodrilus udekemianus			3
Tubificinae	16	20	2
VENEROIDA			
Corbicula	2		
Pisidiidae	15	5	

Macroinvertebrate Bench Sheet Report			
Mar 19, 2019 Saline Creek - [2859_1.3] - 19033			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina	8	5	
AMPHIPODA			
Crangonyx	1	5	
Hyaella azteca		1	
BASOMMATOPHORA			27
Physella	2	8	
COLEOPTERA			1
Agabus			
Berosus		2	
Dubiraphia		2	
Dytiscidae		1	1
Microcylloepus pusillus			
Optioservus sandersoni	1		
Paracymus		2	
Psephenus herricki	4	1	
Scirtidae	1		2
Stenelmis	5		
DIPTERA			5
Ablabesmyia		1	
Ceratopogoninae	1	7	1
Chironomidae			
Chironomus		2	1
Clinocera	85	1	
Clinotanytus		1	3
Corynoneura		2	77
Cricotopus/Orthocladius	186	55	3
Cryptochironomus		3	
Diamesa	1		1
Dicrotendipes		8	1
Diptera		1	5
Eukiefferiella	89	5	1
Glyptotendipes			1
Hemerodromia	54	1	1
Hydrobaenus		17	7
Labrundinia		1	
Microtendipes	1		1
Nanocladius			
Natarsia		2	
Nemotelus		1	
Neoplasta	3		
Parametriocnemus	2		

Paraphaenocladus		2	39
Paratanytarsus	6	3	1
Paratendipes		17	1
Pericomaina		1	6
Phaenopsectra		14	1
Polypedilum aviceps	2		
Polypedilum flavum	2	1	
Polypedilum halterale grp		8	
Polypedilum illinoense grp	1		
Polypedilum scalaenum grp	1	8	2
Pseudochironomus	1		4
Rheocricotopus	1		8
Rheotanytarsus	9	1	
Simulium	10	2	1
Smittia		1	9
Stempellinella	1	19	
Stictochironomus		2	
Sympotthastia	4		
Tabanus	*		19
Tanytarsus	19	30	2
Thienemanniella			23
Thienemannimyia grp	4	3	*
Tipula	1		2
Tribelos		25	
Tvetenia bavarica grp	1		3
Zavrelimyia			
EPHEMEROPTERA			
Acentrella	1		2
Acerpenna	9		9
Caenis latipennis	24	7	
Centroptilum		1	2
Eurylophella enoensis			
Isonychia bicolor	5		
Stenacron		2	*
Stenonema femoratum	4	2	1
Stenonema pulchellum	11		
LUMBRICINA			
Lumbricina		1	
MEGALOPTERA			
Corydalus	1		
NEOTAENIOGLOSSA			1
Hydrobiidae			
ODONATA			4
Argia	1		1
Calopteryx			1
Didymops			6
Enallagma			

Gomphidae	1		1
Gomphus		2	
PLECOPTERA			*
Clioperla clio			
Isoperla	1		
Neoperla	2		2
Perlesta	15		
TRICHOPTERA			1
Cheumatopsyche	27		
Chimarra	5		1
Dibusa angata	11		
Hydroptila	12		1
Ochrotrichia	4		3
Polycentropus			*
Ptilostomis			
Rhyacophila	1		1
Triaenodes			
TRICLADIDA			
Planariidae		1	
TUBIFICIDA			1
Branchiura sowerbyi			1
Enchytraeidae	4		1
Limnodrilus claparedianus			
Limnodrilus hoffmeisteri		1	
Tubificinae	1	14	
VENEROIDA			16
Corbicula	1	8	

Macroinvertebrate Bench Sheet Report			
Mar 19, 2019 Saline Creek - [2859_1.2] - 19032			
* - large rare			
ORDER: Observed Taxa	CS	NF	RM
"HYDRACARINA"			
Acarina	15	16	2
AMPHIPODA			
Crangonyx	2	1	12
BASOMMATOPHORA			
Physella	5		5
COLEOPTERA			
Agabus			1
Ancyronyx variegatus		1	
Dubiraphia	1	1	
Optioservus sandersoni	1		1
Psephenus herricki	5	1	
Stenelmis	2	1	3
DIPTERA			
Ablabesmyia		5	
Ceratopogoninae	1	8	
Chironomidae		1	1
Chironomus		6	
Cladotanytarsus		2	
Clinocera	44	3	1
Corynoneura	2	1	7
Cricotopus/Orthocladius	101	12	97
Cryptochironomus	1	5	
Diamesa	1		
Dicrotendipes		4	3
Diptera		*	
Dolichopodidae		1	
Eukiefferiella	71	2	10
Hemerodromia	11		2
Hydrobaenus	1	7	
Micropsectra	2		
Microtendipes		1	
Myxosargus	2	1	
Nanocladius			1
Orthocladius (Euorthocladius)	1		
Parametrioctenus	2	2	1
Paratanytarsus		3	30
Paratendipes		13	2
Phaenopsectra		5	4
Polypedilum aviceps	13		1
Polypedilum flavum	3	4	1
Polypedilum halterale grp		63	

Polypedilum illinoense grp			2
Polypedilum scalaenum grp	1	4	1
Procladius			1
Pseudochironomus	2		
Rheocricotopus	4		1
Rheotanytarsus	1	1	12
Simulium	12		2
Stempellinella	4	14	8
Stictochironomus		3	
Tanytarsus	14	30	21
Thienemanniella	1		4
Thienemannimyia grp	11	1	18
Tipula	2		*
Tribelos		9	1
Tvetenia bavarica grp	1		
Zavrelimyia			1
EPHEMEROPTERA			
Acerpenna	22		5
Caenis latipennis	9	5	6
Eurylophella bicolor	1		
Isonychia bicolor	13		2
Plauditus	1		
Stenacron	1	1	
Stenonema femoratum	1	1	1
Stenonema mediopunctatum	1		
Stenonema pulchellum	10	4	1
Tricorythodes	1		
GORDIOIDEA			
Gordiidae		*	
ISOPODA			
Caecidotea (Blind & Unpigmented)		1	
LUMBRICINA			
Lumbricina	2		
LUMBRICULIDA			
Lumbriculidae			1
ODONATA			
Argia	1		5
Calopteryx			1
Enallagma		1	4
Gomphidae	2		
Libellula			1
PLECOPTERA			
Chloroperlidae	1		
Isoperla	3		
Neoperla	1		
Perlesta	5		2

TRICHOPTERA			
Cheumatopsyche	11		8
Chimarra	16		1
Dibusa angata	1		1
Hydroptila			4
Mystacides		1	
Oecetis		1	2
Polycentropus			3
Pycnopsyche			*
Trienodes			2
TRICLADIDA			

Planariidae	5	1	3
TUBIFICIDA			
Branchiura sowerbyi		1	
Enchytraeidae	3		
Limnodrilus claparedianus		1	
Limnodrilus hoffmeisteri		5	
Limnodrilus udekemianus		2	
Tubificinae	1	36	1
VENEROIDA			
Corbicula	6	1	1

Appendix B

**Aerial Photos – Little St. Francis River,
Village Creek, and Saline Creek Stations, Madison County, Missouri**

